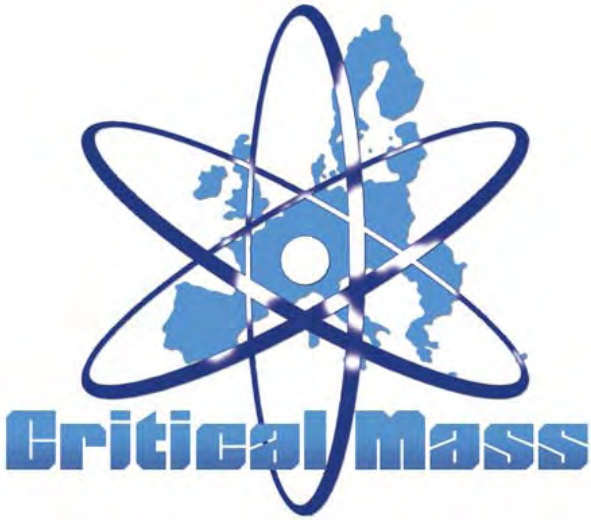
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Study

On the critical mass of public R&D programmes
A potential driver of joint programming



Final Report

20.07.2011

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More information is available at www.criticalmassproject.eu

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Executive Summary

Context and objectives

Reaching Critical Mass is generally considered to be a key element in the policies dealing with the often fragmented and diverse field of EU R&D. This study addresses the characteristics of Critical Mass, and aims to ascertain whether, in selected S&T areas, public R&D programmes in Europe are individually and collectively achieving Critical Mass.

Full objectives of this project are: (1) to define the Critical Mass of public R&D programmes, (2) to assess whether, and to what extent, public R&D programmes in Europe, in selected S&T areas, are individually and collectively achieving Critical Mass, (3) to explain why/why not the public R&D programmes in Europe in these selected S&T areas are individually and collectively achieving Critical Mass and (4) to reflect on possible policy implications.

The primary concern is that Critical Mass in this context and its determinants are not well defined. The way in which the term is being used in policy documents or evaluation reports points to the fact that Critical Mass can be seen as a goal of research policy in itself.

The first activities of this project have qualified and altered this view. In this study, we follow the idea that **the achievement of Critical Mass in public R&D programmes is not a goal in itself, but rather a means with which to reach particular objectives of research policy**.
The scope of the investigation is the ERA-NET scheme, which was launched under FP6 for the purpose of stepping up the cooperation and coordination of research programme activities carried out in Member States and Associated States at national or regional level, putting in place design and coordination mechanisms aimed at networking research activities, including the development and implementation of joint activities. But it has to be strongly underlined that the present study is of an explorative nature and should be considered neither as an evaluation of the ERA-NET scheme nor as an evaluation of the ERA-NETs.

Approach

Given the assertion that Critical Mass is an objective-driven concept, the study took a multi-dimensional approach.

The first step of the study was a broad review of the literature. The elements drawn from this review made it possible to build an original Critical Mass definition and a connected Analytical Framework. The study has fruitfully used analytical concepts that cover a wide range of issues -

from a purely economic perspective to the analysis of policy or policy evaluation. These analytical concepts include:

- production function based approaches, which provide the theoretical background of concepts such as scales or scope economies
- concepts derived through a more dynamic approach, which in particular provide the framework for analysing the development of competencies and changes in network properties
- concepts that enable to take into account the different dimension of the resources and outputs of research activities, projects, or programmes
- concepts that are related to the issue of coordination of resources

The main output of the Analytical Framework has been the specification of a set of indicators to empirically test the validity and appropriateness of the Framework itself.
Having validated these results with high-level experts, we applied the conceptual framework to a case study methodology that included:

1) The development of an online questionnaire that was aimed at a selection of the owners and managers of public R&D programmes (in particular, Coordinators and Participants of the ERA-NET scheme)
2) Putting additional complementary questions to a sub-sample of these participants through face-to-face interviews
3) Carrying out empirical analyses on the data collected as well as on external data
4) Completing the above with further desk research in order to gather additional information on the participants and programmes in the Case Studies

The results of both the online survey and the interviews produced a set of homogeneous data for analysis. The dataset was built at respondent level, whilst groupings of respondent's answers led to two additional and parallel datasets: one at programme level and the other at sector level.

In addition to analysing ERA, a comparative analysis of countries outside the EU was carried out, looking at initiatives to coordinate research policies and programmes in Brazil, Russia, India, China and the US. The goal of this preliminary comparative exercise was to assess whether these other countries have Critical Mass as a policy objective, show similar rationales for the creation of Critical Mass, what instruments these countries use to achieve a Critical Mass objective and whether our definition of Critical Mass is valid in the context of the third countries as well.

All the methodologies used throughout the project led to the development of Policy Implications and Recommendations, which describe the correspondence between the theoretical and empirical

findings of the project. Our recommendations are based on strong empirical data and are supported by a solid theoretical foundation. In fact, a summary of the supporting empirical evidence has been included with each recommendation.

Definition

The concept of the Critical Mass of public R&D programmes is intrinsically related to the R&D activities funded by the programmes. We therefore assume that the Critical Mass of a R&D programme is reached when reaching a Critical Mass is possible in terms of R&D activities. By definition, there cannot be Critical Mass of an R&D programme if R&D activities are unable to achieve Critical Mass.

Reaching Critical Mass in R&D activities has no meaning unless one specifies what this Critical Mass allows/or will allow; in other words, the concept of Critical Mass has to be related to a set of specific policy objectives.

The review of the literature in various fields (physics, social networks, management etc.) and interviews with experts, led us to conclude that there is no single widely accepted definition of the concept of Critical Mass, but rather that a wide variety of different concepts exists. However, the various approaches may be unified to some extent by linking them to different objectives.

We therefore propose the following definition of Critical Mass, obtained partly or entirely because of the presence of these features in R&D programmes:

Threshold level of resources required during a certain period of time in order to achieve a certain type of objective i.e.:

- to address techno-scientific challenge, and/or
- to secure a certain level of competences for defensive or prospective reasons, and/or
- to reach excellence, and/or
- to reach self-sustained dynamics

These objectives are not mutually exclusive, and there may be overlaps, especially between "reaching excellence" and the others. One could also consider that "securing a certain level of competences for prospective reasons" is a pre-requisite for "reaching a self-sustain dynamics" and *a fortiori* for "addressing socio-technological challenges"; alternatively, "securing a certain level of competences for defensive reasons" is only relevant when the scientific / technological field in question has already been largely developed.

Critical Mass Analytical Framework

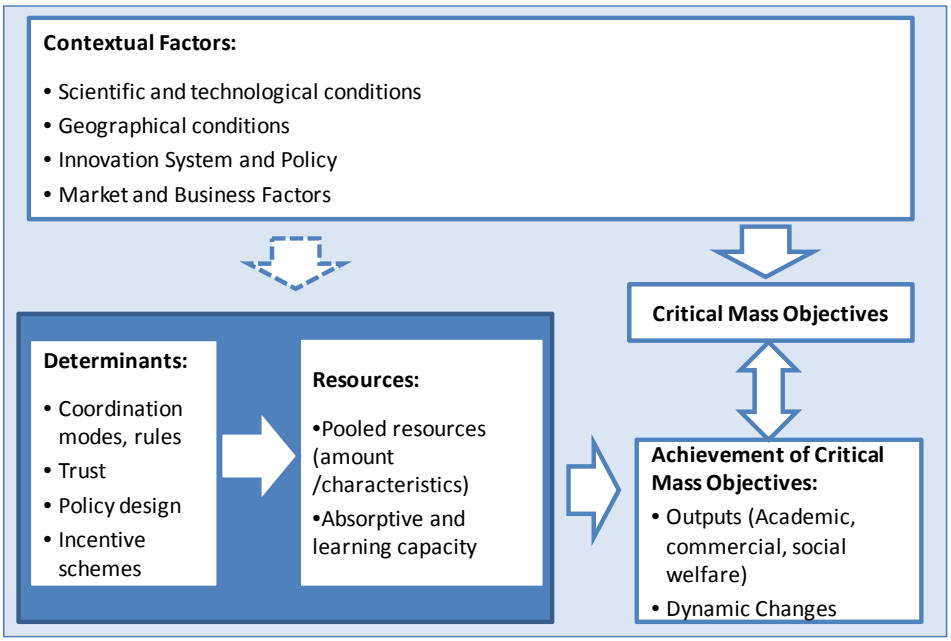
The analytical framework describes the elements of Critical mass and the relationship between these elements (notably causal relationships), which explain how the Critical Mass objective is reached:

- A public R&D programme is one of the means to mobilize resources. However, resources alone are not sufficient to secure Critical Mass: under certain conditions, in part policy driven, they need to be pooled. Facilitative conditions (cf. contextual factors and determinants) are necessary and even "critical" for resources to reach Critical Mass. These elements are not part of our definition, but they are important building blocks in our analytical framework
- Research participants are carrying out R&D activities at least partly within the framework of R&D programmes. The research they are conducting by pooling their resources either results in the achievement of the different objectives related to Critical Mass, or not

Different dimensions have an impact on either R&D policy and programmes, or the way research is carried out and the how the results of the research relate to Critical Mass objectives. Some are directly driven by policy through the design and implementation of R&D programmes, others are contextual in the sense that they are related to the nature of the research fields in question and/or to a broader perspective of the scope a particular research field. In addition to Critical Mass objectives and their achievement, the dimensions of the analytical framework can be identified as: resources, determinants and contextual factors.

A series of different hypotheses can be put forward concerning the linking of the different elements of the analytical framework. The first series of hypotheses considers the way in which contextual factors lead to the determination of Critical Mass Objectives, such as techno/scientific, geographical and market/business factors, and the connection to other research fields. The hypotheses that follow consider the influence that contextual factors (such as research infrastructures, the geographical proximity of resources, the connection of S&T fields to other S&T fields etc.) and determinants have on achieving CM when some of the resources with similar characteristics are pooled.

Figure 4.1 Critical Mass Analytical Framework and its dimensions



All the hypotheses put forward in the Analytical Framework, as well as the definition of Critical Mass and its dimensions (resources, determinants, contextual factors) were applied to a specific case. The specified case was the ERA-NET scheme that presents several of the characteristics needed to analyse Critical Mass: it is a public R&D programme; it implies coordination at international (EU) level and it makes it possible to gather good data.

ERA-NET case studies and analyses

Of the 71 ERA-NETs funded under FP6, 52[1] were included in the online survey. Thirteen of these 52 were then selected for an in depth analysis through case studies based on two key criteria:

- The first regarded the continuation of FP6 activities
- The second involved comparing the different sectors and selecting ERA-NETs with similar general characteristics

Each of the 13 selected ERA-NETs was analysed by means of the online questionnaire (slightly different for coordinators than for participants) and face-to-face interviews of the coordinators and three or more participants.

The ERA-NET scheme presents several factors to which the Analytical Framework can be easily applied. An important particularity of ERA-NETs is that they include "participants", i.e. programme owners and programme managers who represent countries and/or regions involved in an ERA-NET

[1] Those active in the Environment, Industrial Technologies and SMEs, Life Sciences and Transport sectors

scheme. The nature and composition of these participants, and the possibility that they might have past experiences in common, obviously have a significant influence on the design and implementation of the different activities, be they only coordination activities or activities more directly oriented towards R&D activities.

The Critical Mass Analytical Framework makes it possible to explain how Critical Mass is achieved on a case-by-case basis (at the level of individual R&D programmes) and collectively (in terms of different EU R&D programmes that have been coordinated). In the empirical investigation however, we have focused on the latter. In fact, data gathered from the ERA-NET case study through the online survey and interviews, gives an authoritative view of collective achievement.

Achievement of Critical Mass in ERA-NETs

As a first step, we identified the relevant policy objectives for each ERA-NET using the self-assessment undertaken by the respondents and indicators of the contextual factors of the S&T area. As a result, the way we suggest how Critical Mass objectives can be measured, leads to the identification of an average of two objectives per ERA-NET (1.8 precisely). The objective of reaching excellence prevailed and this was followed by the addressing of socio-technological challenges and reaching self-sustained dynamics. Addressing specific scientific challenges applied to a quarter of the cases, but the objective of securing competencies for defensive or prospective reasons appears rather seldom. These numbers appear to be quite plausible, as, for example, reaching excellence is a very basic rationale of the ERA. Other numbers show that ERA-NETs comprise a larger share of application-oriented fields than basic research fields.

Indicator profiles defined for each objective provided the basis for measuring achievement, and based on that measurement, it appears that not all of the objectives identified as relevant policy objectives for ERA-NETs have been reached. We also noted achievements relative to objectives that had not been identified in the first place.

Checking for achievement of the intended objectives showed that all objectives have been reached, but at different levels.

The good results in terms of achievement were not unexpected. The ERA-NET scheme is well known as a successful measure and one that provides good results, and our study has provided further confirmation of this. It seems that many of the ERA-NETs are also able to perform well in terms of pooling Critical Mass in order to address certain policy objectives. In this respect, it also makes sense that we found that some ERA-NETs in particular, namely those addressing socio-technological challenges, had not reached their objectives, but one would expect this kind of objective to take a long time to be realized.

The Critical Mass of Resources Relevant to the Achievement of different policy objectives

Our analyses highlighted that different profiles or combinations of determinants explain the type of Critical Mass (i.e. the achievement of the related policy objectives). The following overview summarises the results of the analysis of ERA-NETs.

- The Critical Mass required to **achieve the objective of addressing socio-technological challenges is generated by** the following combination and prerequisites of determinants and resources:
  - R&D projects with a clear development orientation
  - A high number of partners[2] participating in ERA-NET calls
  - The increase of highly effective coordination / management of the ERA-NET concerned
  - A large budget allocated in the calls of the ERA-NET
- The Critical Mass required to **achieve the objective of addressing scientific challenges is generated by** the following combination and prerequisites of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - The existence of projects (expected to) lead to radically new results
  - On average, the allocation of a large budget for each ERA-NET call
- The Critical Mass required to **achieve the objective of securing competencies for defensive reasons is generated by** the following combination and prerequisites of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - The highly effective coordination / management of the ERA-NET concerned
- The Critical Mass required to **achieve the objective of securing competencies for prospective reasons is generated by** the same combination and prerequisites of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - A high consistency in the motivations of the individual ERA-NET partners
- The Critical Mass required to **achieve the objective of reaching excellence is generated by** the following combination and perquisites of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - A high consistency in the motivations of the individual ERA-NET partners
- The Critical Mass required to **achieve the objective of reaching self-sustained dynamics is generated by** the following combination and prerequisites of determinants and resources:
  - A high consistency in the motivations of the individual ERA-NET partners
  - A high number of partners participating in ERA-NET calls

[2] Partners in ERA-NETs are programme owners and managers, such as public administrations and agencies

- A smaller number of beneficiaries per research project
- A high amount of EC funding required to coordinate an ERA-NET

We estimated the robustness of these results as follows: Regression analyses made it possible to conclude that the combination of identified factors contributed to the achievement of policy objectives (of ERA-NETs). Being based on a small sample, these results should be regarded with caution. For example, we have not reached any conclusions, based on these results, about the quantitative threshold of resources needed, as we consider the number of cases (between 36 and 46) to be too small for such a conclusion.
However, the overall explanatory power of the models, whose values range from 31.1% to 45.1%, is at a very good and reliable level.

Do the results confirm the hypotheses?

Based on the literature review on the concept of Critical Mass as well as on a logical analysis, and adjusting with some input from the different case studies, we had set up a series of hypotheses on the achievement of the different types of Critical Mass. Comparing these hypotheses and the results summarised above, some interesting aspects and qualifications appear.

- Not the number of participants that are members of an ERA-NET is key, but the **number of participants who are in fact regularly active and involved in the main activities** of the ERA-NET.

- Likewise, what is important is the **overall amount of money pooled** together in ERA-NET calls, rather than the number of calls itself (although of course there is a positive relationship between number of calls and the overall call budget pooled by an ERA-NET).

- The **amount of money for calls** has been assumed to be relevant for all objectives, in particular for reaching excellence, while in fact it appears to be relevant mainly for addressing socio-technological challenges and scientific challenges.

- **Effective ERA-NET management** is important for addressing socio-technological challenges - as has been expected, but also for securing competencies for defensive reasons. Here, the indicator rating the overall effectiveness has a strong influence, while the coherence of activities is not important for achievement. In the case of achievements with respect to **establishing self-sustained dynamics**, another aspect of coordination is important. Here, achievements increase with higher amounts of **EC funding for ERA-NET coordination**.

- The **coherence of individual motivations** of ERA-NET partners appears as an important success factor for **securing competencies for prospective reasons**, for **reaching excellence**, and as a most important factor for **reaching self-sustained dynamics**.

- Although Critical Mass is often used as a synonym for reaching large scale or large scope, or at least hinting at increasing size at project or programme level, these results appear to give evidence that Critical Mass is not related to project size (in terms of partners), especially for addressing socio-technological or scientific challenges. We find, that for ERA-NETs striving to establish **self-sustained dynamics** of a scientific field, a **small number of beneficiaries per project** is an important determinant – contrary to what has been expected.

How do these results relate to the results of the qualitative in-depth case studies?

The results from the 13 Case studies principally **confirm and qualify the quantitative analysis**. They give **particular weight to the role of participants and the coordinator**. For example, they emphasize the need for participants to have pre-existing links or in the event that they don't, the need to focus on building trust and commitment, which is done, for example, via the non-R&D activities of the ERA-NET. Participants need to be strongly committed to the ERA-NET policy (i.e. their motivations should be similar). The coordinator's own interests and his management qualities also play a crucial role.

Comparison to other countries

With regard to non-EU countries (BRICS and the USA), the study concludes that the US research and innovation policy clearly addresses the notion of generating Critical Mass – but maybe not always in explicit terms. However, the mission-orientated nature of US policy implies pooling a Critical Mass of resources. This is also true for the excellence orientation inherent in US innovation policy. For some efforts, there is also available evidence that documents success and impact. More specifically, single initiatives follow specific objectives. The National Nano-technology Initiative for example, addresses socio-economic and scientific challenges in the same way. Above all, however, it aims to secure a leading position in the field for the US. It can be assumed that a wider recapitulation of US research and innovation policies would arrive at the conclusion that all objectives related to Critical Mass play a role, i.e. also those relating to very young research fields or small/ unconnected research communities.

As regards Brazil, the analysis has shown significant evidence showing that it is addressing the following Critical Mass objectives: socio-technological challenge, securing competencies for prospective purposes and self-sustained dynamics.

Russia is an example of a rather centralized system. In the case of CM analysis, the Federal Target Programmes (FTP) seem to be the most interesting programmes for coordinated (thematic) research. The programmes laid out in detail in the annex focus on socio-technological challenges and to a lesser extent on scientific challenges in as much as the programmes aim to create new knowledge and new research fields. This is especially true for the Nano-scientific programmes but also the Glonass-Satelite programme. All in all, the rather centralized Russian support system shows various signs of transforming Russia into an innovative economy. Therefore, much of the funding is also devoted to securing competencies for prospective purposes.

In summarizing case of India, it must be acknowledged that the current innovation policies and coordinated programmes have to address several issues at the same time: helping to solve societal challenges (e.g. rural poverty), trying to acquire knowledge of future technologies with high market potential (e.g. bio-technology or Nano-technology), and competing with world-class research facilities located outside its borders in the industrial countries.

In terms of Critical Mass orientation, there is a strong tendency towards Excellence and trying to meet Socio-technical challenges.

As to China, it seems obvious that innovation policies are primarily geared towards economic growth. In a rather tentative manner, the most likely types of Critical Mass that apply to the Chinese case would be self-sustained dynamics and securing competencies for now and the future. However, there are also a number of indications that the other Critical Mass objectives, such as national/societal challenges (sending a Chinese national to the moon) and Excellence are addressed too.

This comparison – although limited to desk research – may illustrate the role the notion of Critical Mass plays outside the EU. Even if rarely mentioned explicitly and never defined, Critical Mass and to an even greater degree, the objectives that can be addressed by pooling a Critical Mass of resources, are a relevant issue everywhere. This kind of research is limited, as it cannot systematically assess how well these countries perform in pooling Critical Mass. In the analyses for another part of the project, we have approached this by analysing the patent and publication output not only of European institutions, but also of institutions located in the US and the BRIC countries. This kind of analysis cannot causally link the observed output to certain policy measures, but it can illustrate the strengths of the countries and regions in different selected disciplines, i.e. it can show and compare the level of excellence achieved by different research communities worldwide.

Implications and recommendations

Policy implications and recommendations related to policy objectives linked to Critical Mass include:

I. Critical Mass is a central means to reach policy objectives associated with the European Research Area

II. Reference to the Critical Mass concept in EU policy should always be accompanied with a link to Policy Objectives, as different Policy Objectives imply different types of Critical Mass

III. Policy objectives of the ERA vary across sectors and time and policies aimed at pooling Critical Masses associated to the objectives need to be based on consensual definitions and analyses of the evolutionary state of sectors

Policy implications and recommendations related to the generalization of the analytical framework include:

IV. The framework developed in this study for measuring and analyzing Critical Mass has potential to be applied to policy objectives of different R&D programmes

V. The knowledge base established in this study needs to be constantly expanded using data from the empirical analysis of the ERA-NET and other programmes

VI. The availability of standardized records and keeping track of the Beneficiaries of R&D programmes is necessary for empirical analysis

Policy implications and recommendations about key resources based on evidence from ERA-NETs include:

VII. The achievement of Critical Mass depends on the number of national governments being part of joint activities and on national governments (programme owners) being committed to similar individual goals. Bottom-up approaches appear to be a helpful basis for building common visions, trust and commitment

VIII. Effective Coordination is linked to the achievement of Critical Mass and its related policy objectives, and should therefore be given particular support

IX. Promotion of joint funding activities is of importance, in an indirect manner, because it leads to increased opportunities for researchers to collaborate

X. Rather than focussing on the overall sizes and budgets of projects and programmes, more attention could be given to the importance of the (average) funding of individual participants of specific programme actions

1 Introduction

This report presents the results of a study entitled “On the Critical Mass of public R&D programmes - A potential driver of joint programming” (hereafter “Critical Mass”), commissioned by the European Commission, Directorate-General for Research and Innovation, to the consortium formed by Fondazione FORMIT, BETA and Fraunhofer ISI.

The investigative scope of the Study was the concept of Critical Mass within the European Research Area (ERA). The document issued by the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions,”Towards a European Research Area” (COM (2000) 6 final), issued on 18 January 2000, defined the common ground for a European Research Area. Since its birth, the main scope of the ERA has been focused on facing some perceived weaknesses in the field of Science and Technology and, in particular, insufficient financial resources, lack of an environment that would stimulate research and exploit its results and the fragmented nature of activities and dispersal of (not only financial) resources.

Such issues are directly connected to the Critical Mass concept. The European weaknesses mentioned above are usually perceived in fact as the absence of instruments and dynamics to bring the existing capabilities dispersed throughout EU territory, together. Being dispersed, such local/national strengths lie below the threshold for becoming a common EU-wide strength. Furthermore, the main tool for reversing this phenomenon – that is the creation of European transnational public R&D programmes – still seems to be ineffective in achieving its objective.

Therefore, the focus of this Study has been the Critical Mass of European public R&D programmes: it is often argued that public R&D programmes in Europe are individually and/or collectively not achieving "Critical Mass". Yet it is not entirely clear what is meant by Critical Mass in this context, or what the determinants of Critical Mass are. Clarifying these issues has been the purpose of this study. More specifically, the objectives were:

- To define what is meant by the Critical Mass of public R&D programmes and assess whether, and to what extent, in selected scientific and technological (S&T) areas, public R&D programmes in Europe are individually and collectively achieving Critical Mass;
- To explain why (or why not), in these selected S&T areas, the public R&D programmes in Europe are individually and collectively achieving Critical Mass.

Such objectives have been addressed using a theoretical approach and empirical analysis based on the Case Study activities of a specific EU public R&D programme, namely the ERA-NET scheme. It has to be underlined that the present study is of an explorative nature and should be considered neither as an evaluation of the ERA-NET scheme nor as an evaluation of the ERA-NETs.

The structure of the report is as follows:

- Chapter 2 outlines the methodological approach to the Study: the multi-dimensional approach adopted – through theoretical, qualitative and quantitative analyses – is explained in detail.
- Chapter 3 presents the latest definition of Critical Mass: this has been derived from the results of a review of the literature and interviews with experts.
- Chapter 4 details the Analytical Framework for analysing Critical Mass: the definition for Critical Mass has been broken down into elements (Contextual factors, Determinants, Resources, Objectives) that have been studied separately and within a common framework.
- Chapters 5 and 6 respectively present the rationale for Critical Mass analysis through the Case Study of ERA-NETs as well as its actual measurement, the empirical tools used to gather new data (the online survey, interviews with public R&D programme owners and managers,) and the way they have been analysed are presented. The Critical Mass Analytical Framework makes it possible to explain Critical Mass achievement both individually (at the level of individual R&D programmes) and collectively (in terms of the coordination of different EU R&D programmes). In the empirical investigation of chapter 6, however, the focus was on the latter.
- Chapter 7 reports on a preliminary comparative study of coordinated research programmes in other countries: a concept similar to that of Critical Mass was sought for in R&D programmes launched in the US and in the BRIC countries.
- Chapter 8 outlines policy implications and recommendations: these are based on the key findings and achievements of the Study and divided into three broad sections - the concept of Critical Mass, a generalisation of the Analytical Framework presented in this Study and the specific case of the ERA-NET scheme.
- Chapter 9 summarises the overall conclusions and insights drawn from the Study.

2 Methodology of the Study

In this chapter, we outline the methodology adopted in the Study to analyse Critical Mass. Particular attention is devoted to the multi-dimensional perspective of the approach in connection with the cross-disciplinary origins of the Critical Mass concept.

The focus of this study has been on the Critical Mass of European public R&D programmes starting from the point that it is often argued that in many S&T areas public R&D programmes in Europe are individually and/or collectively failing to achieve "Critical Mass". The main issue is that it is not entirely clear what is meant in this context by Critical Mass, or what the determinants of Critical Mass are. The way in which the term is being used in policy documents or evaluation reports points to the fact that Critical Mass can be seen as a goal of research policy in itself (e.g. EC 2004, Juhlin et al. 2009). A similar view is brought forward by the OECD innovation strategy (OECD, 2010). One example of a more explicit working definition of Critical Mass is the report of the ERA-NET+ review panel. It states that: "…Critical Mass is achieved when a network reaches a combined level of research effort, partner support and resourcing that is sufficient to enable significant progress to be made in tackling a common research challenge" (Lock et al., 2009).

Therefore, the methodological approach of the Study was drawn up to include all the existing elements regarding the concept of Critical Mass and to exploit all theoretical, qualitative and quantitative tools in order to better embrace the multi-dimensionality of this concept.

2.1 The original approach of the Study: a multi-dimensional perspective

The first activities in this project qualified and altered this view. In this study, we pursue the idea that **the achievement of Critical Mass in public R&D programmes is not a goal in itself, but rather a means to reach certain objectives of research policy**. This view led to the main objectives of this study: to define the Critical Mass of public R&D programmes; to assess whether, and to what extent, in selected S&T areas, public R&D programmes in Europe are individually and collectively achieving Critical Mass; to explain why/why not in these selected S&T areas, the public R&D programmes in Europe are individually and collectively achieving Critical Mass; to reflect on possible policy implications.

Given the assertion that Critical Mass is an objective-driven concept, we took a multi-dimensional approach to the study. One the one hand, we took into account the qualitative information obtained directly from the expertise of scholars and practitioners, chiefly through interviews conducted with experts and specifically the WP2 interviews and then at the WP4 Validation Workshop. Similarly, we also conducted interviews with the participants that constituted the reference target of the study – that is public R&D programme owners and managers – during the WP3 Case Study work. Analysis of the literature also represents one of the main sources of information from scholars on the topic, albeit indirectly. On the other hand, quantitative

information was gathered throughout the entire project. A case in point is the Online survey launched during WP3 and external information obtained (e.g. on patents and publications in the scientific field of the Case Study) during WP4. The Online survey in particular has allowed us to gather direct information on the perception of Critical Mass by respondents, as well as indirect information on its achievement. Some questions, in fact, were aimed at empirically quantifying Critical Mass.

A multi-dimensional and cross-disciplinary approach was followed throughout all the activities of the project, as presented below.

2.1.1 Review of the Literature and Analytical Framework

A large number of articles, books and reports use the concept of Critical Mass without actually defining it and it seems that no single and widely acknowledged definition of this concept exists. Historically, the concept of Critical Mass comes from nuclear physics, but it was swiftly adopted by other scientific fields. In reviewing the literature, we have therefore examined contributions from a variety of field (physics, biology, business, sociology and economics). Important insights were also obtained by applying percolation theory and from literature about the diffusion of innovation. Finally, European Policy documents were also taken into account.

Table 2.1 Some interdisciplinary definitions of Critical Mass

Nuclear physics (Schelling, 1978)	***"An atomic pile « goes critical » when chain reaction of nuclear fission becomes self-sustaining; for an atomic pile, or an atomic bomb, there is some minimum amount of fissionable materials that has compacted together to keep the reaction from petering out... The principle of Critical Mass is so simple that it is no wonder that it shows up in epidemiology, fashion, survival and extinction of species, language systems, racial integration, jaywalking, panic behaviour, and political movements."***
Economics of R&D, evaluation of EC/FP Brite-Euram programmes (Bach et al., 1995)	***In the: "[Some effects] tend to describe the impact of the project on the "human capital" of the participant. Each of the participating organizations masters a certain range of competences related to more or less diversified scientific and technological fields, which form what has been called the "Critical Mass" or the "knowledge base" of this organization."***
Evaluation of the effectiveness of the New Instruments of FP VI (EC, 2004)	***"The Commission has not properly defined the concept of 'Critical Mass' and participants have often constructed artificially large consortia perceiving size and composition to be determinant for success, while excellence should be the determining factor"***

All the information drawn from the literature review have made it possible to build a new definition of Critical Mass, and a connected Analytical Framework that will be presented in chapters 3 and 4 respectively. These have fruitfully used analytical concepts and cover a wide scope of issues, from a purely economics perspective to the analysis of policy or policy evaluation. Among the analytical concepts used, we note:

- those based on a so-called production function approach, which provides the theoretical background of concepts such as scale or scope economies
- those derived from a more dynamic approach that provide the framework for analysing the development of competencies and changes in network properties in particular
- those which make it possible to take the varying amplitudes of the resources into account along with the results of research activities, projects, or programmes
- those related to the issue of the coordination of resources

Therefore, the most important outcome of the Analytical Framework has been the individuation of a set of indicators to empirically test the validity and appropriateness of the Framework itself.

2.1.2 Experts' interviews and the Validation Workshop

Among the means used in the study to provide a definition of Critical Mass as well as its measurement, the interviews with experts have played a pivotal role. They were involved in two different phases of the project: at the beginning, during WP2, to provide insights on the definition Critical Mass definition and at the end, during WP4, to validate the activities carried out throughout the project, and its results.

The interviewees were selected through a cross-disciplinary approach, as shown in the table below, and by considering three elements:

- Their area of professional activity: some experts had an academic profile, others were drawn from a public research environment or from the private sector
- The Geographical provenance of the experts: from throughout the EU
- The Scientific fields of their research: those covered by our experts were very varied

Table 2.2 Characteristics of experts interviewed

Geographical provenience	Type of organisation	Scientific field of research	Sector of professional activity
Belgium	1 Foundation	Biotechnology	Private Sector
Germany	2 Research Centres, 1 University	Aerospace, Research Policy	Academia and Public Research
Italy	2 Universities 1 Research Centre	ICT, Research Policy	Academia and Public Research
France	1 University, 1 Research Centre	Chemistry, Technology Transfer	Academia and Public Research
Luxembourg	1 University	Research Policy	Academia
Spain	1 Research Institute	Research Policy	Public Research
The Netherlands	1 Research Institute	Research Policy	Public Research
UK	1 University	Research Policy	Academia

2.1.3 Case Study: Online Survey and Vis-à-vis interviews

Most of the methodology used during the project is described in the Case Study activities reported in chapters 5 and 6. In order to empirically test the definition of Critical Mass and determine whether it had been reached, the following activities were undertaken:

1) An online questionnaire was developed and submitted to a selection of public R&D programme owners and managers (in particular, Coordinators and Participants of the ERA-NET scheme).

2) Further complementary questions were put to a sub-sample of these participants, through vis-à-vis interviews.

3) Empirical analyses were carried out, both on the database developed through the above-mentioned activities, and on external databases (e.g. the SCOPUS database, in terms of publication analysis, and the 'EPO Worldwide Patent Statistical Database' – PATSTAT – in terms of patent analysis).

4) Desk research was carried out in order to gather additional information regarding the participants picked out in the Case Study.

This multi-dimensional approach has made it possible to take a comprehensive view of the phenomena analysed. A large amount of information was collected through the online questionnaire. With reference to the Analytical Framework's indicators, individuated at the beginning of the project, most were empirically calculated on the basis of the results of the online survey. Some also benefited from the second activity: vis-à-vis interviews helped fill in any gaps or clarified any remaining ambiguities in their answers to the questionnaires.

In the following table, we present the main topics of Critical Mass indicators as individuated by the Analytical Framework and the activity by which they were measured.

Table 2.3 Critical Mass Analytical Framework indicators' topics and activities undertaken

Topic	Online Survey	Vis-à-vis Interviews
Characterisation of the public R&D programme	Yes (differentiated questions, according to type of respondent)	Yes
Characterisation of the Participants in the public R&D programme	Yes	Yes
Activities of the public R&D programme	Yes (differentiated questions, according to type of respondent)	Yes
Characterisation of the projects funded under the public R&D programme	Yes	Yes
Characterisation of projects similar to the public R&D programme but outside it	No	Yes
Outputs, Outcomes and Impacts of the participation in the public R&D programme	Yes	Yes
Environmental conditions of the area of research	Yes (differentiated questions, according to type of respondent)	Yes

In developing the online survey, the prime concern was to adapt the indicators individuated at WP2, rendering the phrasing instantly understandable to an online respondent. This involved the project team in a lengthy period of brainstorming.

An experimental phase of pilot interviews was carried out to test the clarity of questions and how they might be improved. All the steps regarding the strategies adopted for the online survey can be summarized briefly as follows:

- The adaptation of indicators defined in the Analytical Framework to the online questionnaire
- Desk research to individuate the contact details of public R&D programme owners and managers (i.e. Coordinators and Participants of FP6 ERA-NETs)
- Pilot interviews to test the questions developed for the online survey
- The delivery of physical letters of invitation to compile the survey for the selected owners and managers of public R&D programmes
- The launch of the online survey on the Critical Mass website
- Link to the online survey on the European Commission JRC-IPTS website[3]

[3] Thanks to the cooperation of European Commission JRC-IPTS, a direct link to the Critical Mass online survey has been created at: http://netwatch.jrc.ec.europa.eu/nw/

- Survey data collection
- Delivery of email reminders to the sample of public R&D programme owners and managers not yet registered on the Critical Mass website
- Further dynamic improvement of the contact database
- Telephone reminders for registered users that had not yet replied

Vis-à-vis interviews started parallel to the online survey. The main steps undertaken in selecting interviewees from public R&D programmes were:

- To carry out desk research to determine which subjects in the population were best suited to answer the additional questions
- To make initial contact by telephone and/or e-mail to briefly explain the aims and content of the Critical Mass project
- To send an email detailing the topics that would be discussed during the interview
- To carry out the interview at the subject's premises
- In a very few cases, we took advantage of telephone interviews or video-conferences instead of vis-à-vis interviews

2.1.4 Data collection and analysis

The outcome of both the online survey and the interviews was to produce a set of homogeneous data for analysis. This dataset was built at respondent level, whilst aggregations of respondents' answers led to the creation of two additional parallel datasets: at programme and sector levels respectively.

In the first case, all respondents belonging to the same public R&D programme (in particular, for each ERA-NET) were aggregated in order to obtain information about the programme itself. Different methods of calculation were used to obtain data from the two databases, conformant to their disparate requirements:

- The total number of all respondents' answers
- The total number of all of respondents that gave the same answer
- The average of respondents' answers (for numerical variables only)
- The most frequent answer
- Further calculations using multiple answers

The possibility to create an additional dataset arose from answers that were similarly aggregated at sector level, using all the answers given by respondents from public programmes in the four selected sectors (as explained in chapters 5 and 6, these four sectors are: Environment, Industrial Technologies and SMEs, Life Science and Transport).

In addition, other data sources – such as the patents and publications databases – were used to complement the information gathered through the online survey.

Finally, the empirical analyses used to measure Critical Mass (as presented in chapter 6) were undertaken using three methodologies:

- Descriptive statistics
- Bivariate correlations
- Simple regressions

2.1.5 Comparison with other Research Policies and Programmes

A comparative analysis was also carried out of countries outside the EU countries, looking at initiatives to coordinate research policies and programmes in Brazil, Russia, India, China and US. The goal of this comparative exercise was to assess whether these countries show similar rationales for the creation of Critical Mass, what instruments these countries use to succeed in their respective projects and whether the definition of Critical Mass is valid in other contexts as well.

One of the main methodological challenges came from the amount of empirical data on individual programmes in those countries. In this regard, the five countries studied are obviously different with respect to the degree of centralisation of policies at federal/supra-national level, in that historically all developed top-down structures.
Another challenge to making comparisons was the heterogeneity of the group of countries. While the US can be considered a major competitor in terms of scientific development, the BRIC countries are still, in comparison with the EU, clearly disadvantaged in this respect. The heterogeneity between these countries makes the object of comparison blurry and difficult to assess. A serious challenge to making the comparison was also the lack of comparable data.

In order to deal with the above-mentioned difficulties, a multi-faceted view of the countries was adopted, taking current national science and technology plans and secondary literature into account. The goal of this literature review was to identify policy measures of the respective countries, aimed at creating Critical Mass – either in the sense of the framework proposed here or in light of the analyzed programme. A certain degree of data comparability was guaranteed by the use of data sources like Trendchart Country reports and the Erawatch policy measure database. This was done in order to identify individual measures at programme level to see whether they show a notion of Critical Mass or interesting forms of coordinating research policies or programmes that were being operated in a defragmented manner.

2.1.6 Policy Implications and Recommendations

All the methodologies used throughout the project led to the individuation of Policy Implications and Recommendations. These have been written up to show the analogies between the theoretical and empirical advancements of the project. Although these recommendations are

presented in a discursive way and are based on a theoretical approach, they do therefore have a strong empirical basis. Together with each recommendation in fact, a summary of the empirical evidence supporting it is included.

Table 2.4 Methodology of the Study, step by step

	Direct	Indirect
Perception and theoretical view on the Critical Mass	Experts' interviews (WP2); Validation Workshop (WP4) Case Study interviews (WP3) Online Survey (WP3)	Literature review (WP2) Research Policies and Programmes in the USA, Brazil, Russia, India and China (WP4)
Quantitative measurement of the Critical Mass	Online Survey (WP3)	Online Survey (WP3) Publication and Patents analysis (WP4)

3 Critical Mass definition

In this chapter, we present the novel definition of Critical Mass as the first outcome of this Study. In fact, the first aim of the Study has been to provide a definition of Critical Mass since, as already noted, this appears to be missing in economic literature. The concept of Critical Mass in fact, is widely used in several technological fields although it may address very different issues. In the area of R&D and innovation, with specific reference to public R&D programmes, this concept is often associated with some sort of economies of scale in intangible assets. This view is considered only partial and needs to be developed further.

Therefore, this study has led to a definition of Critical Mass in public R&D programmes based on two main sources: a detailed review of the literature (see Annex 1) and recommendations from a panel of experts.

3.1 Main inputs from the literature review

The literature review conducted in this study represented the first activity. Contributions from a variety of fields were examined, namely physics, biology, business, sociology and economics. The main inputs and conclusions that can be drawn with regards to Critical Mass are as follows:

- there is not a single widely accepted definition of the concept of Critical Mass
- there are different definitions in various sciences (including areas of social science), some of which have a sound scientific basis and a well-established selection of literature
- in other fields and contexts, the concept of Critical Mass is frequently used but almost never strictly defined. It therefore remains vague, ambiguous and subject to misunderstanding and misinterpretation
- this is especially so in areas related to R&D policy, in which Critical Mass is either related to notions of fragmented research, fragmented policies, economies of scale or scope or increasing returns, all of which are quite different from a strictly analytical point of view
- when Critical Mass is conceptualized in a detailed and rigorous way, it is always related to:
  - the existence of a threshold of "ingredients" that have to be combined
  - the necessity for those "ingredients" to be combined in a certain way
  - the importance (and sometimes the necessity) of specific conditions under which these "ingredients", when combined together, reach Critical Mass
  - the fact that something happens because that threshold was reached, can more or less be accurately predicted. When an action geared to reach Critical Mass is begun therefore, it is implicit, that it will be reached; in other words, an action geared to achieve Critical Mass is necessarily objective driven
  - what happens as a result of reaching Critical Mass is conceptually different according to the different ways in which Critical Mass is conceived: it could be a new entity (biology), a dynamic and self-sustained reaction (in physics: fission, in infrastructure-type network

analysis: network expansion), the production of a public good (in some social network analyses); a level of competitiveness (in management: overcoming market barriers and in R&D policy rhetoric - keeping up with the USA or with the "Excellence"). In some cases, what is achieved thanks to Critical Mass becomes independent from Critical Mass itself (it is "here once and for all"), in other instances, Critical Mass has to be maintained in order to keep on "producing" that result. In other words, some form of reversibility may or may not be possible.

3.2 Insights from the experts

Interviews with experts were also conducted during this study in order to gain greater insight on the concept of Critical Mass in different fields. The most important data elicited from the experts can summarized as follows:

- There cannot be a single approach to the definition of Critical Mass, but various definitions are needed for particular contexts. These contexts are chiefly determined by the thematic fields / societal challenges addressed by research
- It is difficult to describe research results precisely (in general, and in the definition of Critical Mass) because they evolve over time/geographic contexts and are not homogeneously measured
- Research networking could be considered as an essential condition for research rather than a result or an outcome of Critical Mass
- As to the definition of “Critical Mass”, it would be better to keep the concept of “basic research” separate from that of “applied research”. It is necessary to distinguish between these two spheres when defining Critical Mass, as when applied, that research may affect society, industry and the scientific community at different levels
- It is important to define the main objectives of a research programme launched by ERA-NETs in order to assess its outputs and its impact at different levels: socio-economic, industrial and scientific. Some experts suggested starting with an analysis of the project’s objectives in order to verify whether they have been achieved and to assess what impact they have had
- Even though ERA-NETs are one possible means to reach Critical Mass at European level (a fact that was clear right from the beginning of the project), collaboration at bilateral or regional levels outside the ERA-NETs are equally appropriate
- Some experts suggested inserting a preliminary definition of Critical Mass, to be identified before research programmes get underway. By defining an initial Critical Mass at an introductory, minimal level, it would be possible to develop and monitor the research programme during the different phases of its implementation. Monitoring Critical Mass during the project’s development would make it possible to verify whether the objectives of the programme were contextually achieved and whether the increase of Critical Mass

has a knock-on effect on the outcome and impact expected, such as an increase in knowledge for the scientific community and/or a new patent for industry

- Critical Mass allows the user to achieve something. The output or achievement could be compared with something external, e.g. the output or achievements of the United States innovation system at federal level. The pooling of funds at EU level should increase the excellence of European research as compared to other world regions, or large innovation systems such as those in the BRIC countries or the US. Critical Mass should make it possible to achieve excellence, funding outside FP priorities and dynamics (Influence on Framework Programme, Networks)
- Critical Mass has the potential to generate outputs and its organization and structure are its most important elements. If there is no assigned goal, there can be no Critical Mass
- Critical Mass needs an accumulation of knowledge and competencies, links with industry, legal/economic devices (e.g. patents, collaborative agreements, market knowledge etc.), if it is to ensure goals are reached and that there will be a possibility to exploit and benefit from it
- Critical Mass is about getting people to work together at the same time and at a point in time that is relevant to the socio-economic context, with strong connections (but not necessarily in the same physical place), with the same institutional settings (especially with regard to incentives, rules etc) and with a common objective. Critical Mass is by nature multi-disciplinary; however, the scope of those disciplines depends on how the classification of disciplines is formed. (i.e. fractal phenomena). There is a strong dimension of project management to Critical Mass: leadership and individual characteristics are key to the way Critical Mass is organised. Time matters: the timing of when a window of opportunity appears, does not necessarily match the time required to develop Critical Mass. In those cases there is a need either i) to maintain the basic building blocks of Critical Mass or ii) to have Critical Mass itself at disposal
- In considering Critical Mass as the means to achieving self-sustaining dynamics presumes that Critical Mass requires not only a mass of resources, but also a concentration of resources, so Critical Mass should usually be located in the same geographical area. It is the interactions between researchers (flows/exchanges/combinations of ideas), the channels of communication and their approach to each other that creates the dynamics
- Learning and teaching are factors that should not be forgotten
- Critical Mass as a means of achieving excellence / catching up with leading countries is often put forward in discussions on policy, but that is probably less sound scientifically and analytically than the concepts of Critical Mass that are well established in physics or network analysis
- It is arguable that Critical Mass is compatible with (reachable through) networking remote participants, or with splitting resources for cohesive purposes

- Critical Mass by collaboration beyond national boundaries is necessary if "added value" is to be achieved, especially for small countries like Luxembourg that depend on close interaction with counter parts in what is called *'Le Grand Region'*, comprising, amongst others, Saarland, Lorraine and Luxembourg
- The pooling of resources is particularly important in research that requires inter or multi-disciplinary cooperation, and where facilities or competencies are not sufficiently available

3.3 The definition

The concept of Critical Mass in public R&D programmes is intrinsically linked to the concept of Critical Mass in R&D activities that are funded or motivated by R&D programmes. It is assumed therefore that the Critical Mass of R&D programmes is reached when R&D activities make it possible to reach Critical Mass. By definition, R&D programmes could have no Critical Mass if R&D activities did not lead to Critical Mass being achieved.

Reaching Critical Mass in R&D activities has no meaning unless it is specified what this Critical Mass allows/will allow. In other words, the concept of Critical Mass has to be related to a set of specific policy objectives.
The review of the literature from various fields (physics, social network, management etc.) referred to above, and interviews with experts, led us to conclude that there is no single widely accepted definition of the concept of Critical Mass, but rather that there are different concepts. The different approaches may however be unified to some extent, by linking them to different objectives.

We now propose the following definition of Critical Mass, obtained partly or entirely due to the presence of specific features in R&D programmes.

Table 3.1 Theoretical definition of Critical Mass

Threshold level of resources required during a certain period of time in order to achieve a certain type of objective i.e.: **- to address techno-scientific challenge, and/or** **- to secure a certain level of competences for defensive or prospective reasons, and/or** **- to reach excellence, and/or** **- to reach self-sustained dynamics**

In this context, a public R&D programme is one of the means by which resources could be mobilised. Resources might be very diverse in nature (money, human, infrastructure, etc.) and include some that are more qualitative and intangible (knowledge and competencies).

Resources alone are not sufficient to secure Critical Mass: they need to be pooled together under certain conditions, part of which needs to be policy driven. Although those conditions and enabling factors are necessary if resources are to make it possible to reach Critical Mass - and in this perspective, they could be considered as "critical" - they are not *exactly* part of Critical Mass.
The time dimension is important from two points of view:

- resources pooled together may take time before they can be deemed to have created Critical Mass, because, for instance, the necessary conditions have not all been fulfilled
- resources pooled together to create Critical Mass may need some time before they actually achieve the objective

The definition is clearly objective-driven, and includes different types of objectives. These objectives are considered only at a technological/scientific level and not at a particularly high policy or societal level. Public R&D programmes always follow a set of objectives, but they are not all necessarily linked to Critical Mass issues. For instance, fostering the development of new material useful to several industries might help sustain the competitiveness of those industries but this objective is linked to more traditional failures in coordination (university-industry relationships, the grouping together of different players from different sectors, etc), related to supporting incremental innovation.
The objectives selected in the definition of Critical Mass should therefore correspond to those for which a Critical Mass of resources is an absolute requirement. One could also argue that any level of development in science and technology (expressed, for instance, in terms of output) could be set as a target or as an objective, and then require the mobilization of a minimum level of resources. Nevertheless, the objectives selected in defining Critical Mass coincide with significant steps in developments in science and technology and also correspond to phenomena that are at stake in the various definitions of Critical Mass analyzed in the literature or described by experts.
More precisely, the four objectives might be justified as follows:

To address techno-scientific challenges:
in this case, Critical Mass makes it possible to provide a solution to a challenge, which could be a "purely" technological or scientific challenge, or one that embraces a social element. Here, the notion of challenge is very important in that it differs from a technological problem, which is incremental. By challenge, we do not mean solving an incremental technological problem but rather finding the answer to social issues and developing breakthrough technologies (which requires a multi-disciplinary approach that produces a sizeable ripple effect). Examples of this include: increasing the production of agro-food whilst preserving the environment and natural resources, developing the Galileo satellite navigation system, developing an electric vehicle affordable by everyone - especially in emerging countries, developing green chemistry for sustainable agriculture, forecasting earthquakes and the Human Genome Project which are all social challenges involving technological or scientific challenges.

In the literature, Oliver et al. (1985) defines Critical Mass "as a segment of the population that chooses to make big contributions to the collective action" (p.524). In social network analysis, Critical Mass is associated to the creation of a collective or a public good. Some experts explicitly referred to objectives linked to the development of complex technologies, products or services difficult to introduce in society. They also clearly made the link with the notion of Grands Programmes (in space, defence, telecom/energy/transport infrastructure etc).Thus Critical Mass is needed to address specific challenges and not any type of technological or scientific problem.

To secure a certain level of competences for defensive or prospective reasons:

In this case, Critical Mass makes it possible to maintain a certain level of competencies and knowledge in a given area. This level is just enough to be able to continue to follow developments made in the field and to absorb them. It also forms the nucleus of the "bricks" that can be mobilized so that the first type of objective can be reached.

A "defensive reason" would be in a "traditional area" (e.g. basic metallurgy, Ninth Century Persian literature, very old varieties of cereals, …), that young researchers tend to shun. In these cases, Critical Mass makes it possible to keep accumulated knowledge and competencies alive and mobile. This type of Critical Mass has no break-through objective, but calls for an on-going process based on tacit knowledge that could be mobilized rapidly if needed.

A "prospective reason" would be in a brand new or emergent area, possibly seen as very "original" at a particular point in time (e.g. wind turbines some years ago). In these cases, Critical Mass makes it possible to maintain competencies (i.e. the option) to give it a boost it if it appeared that this area was becoming relevant in changing economic, technical social or market conditions.

For Oliver et al 1985, to maintain a public good, which could be interpreted here as the accumulation of "prospective" or "defensive" knowledge that could be easily mobilized, the people involved in a Critical Mass are more likely to have access to the required knowledge. Some experts underlined that in terms of time, there might be a mismatch between a window of opportunity to develop an innovation and the time necessary to create Critical Mass. There is a need therefore to maintain some basic "bricks" that could be mobilized easily.

To reach excellence:

In this case, Critical Mass makes it possible to be a visible or a key player in any given area. Different points of references can be envisaged: in relative terms (comparison with other players - e.g. USA-Japan-BRICs, ranking - e.g. being a leader or one of the top 3), or in absolute terms.

This objective results mostly from EU policy discussions. The aim of FP6 is to develop scientific and technological excellence in order to create the European Research Area. Reaching excellence and creating the ERA are also explicit goals of FP7.

To reach self-sustained dynamics:

In this case, Critical Mass, is reached when a self-sustained dynamics has been initiated in terms of research activities, thanks to the connectivity between researchers and the involvement of "key players". Involving Nobel Prize Winners, for example, tends to attract other researchers and leading companies in their particular field, interested both in exploring that field and to show that the technology may have market applications. First, the involvement of "key players" slowly starts to attract new players drawn by the promising results, and once Critical Mass has been reached, interest (and adoption of the technology) grows and happens more quickly and in a self-sustained way. Self-sustained dynamics that are linked to networking issues and people's growing interest should lead to high returns in the production of knowledge.

This concept of Critical Mass is clearly based on the one used in different scientific disciplines such as physics, biology or telecommunications. According to Ball (2004), Critical Mass in social network research is a socio-dynamic that illustrates the stage at which a social system becomes self-sustaining and stimulates growth. In the field of innovation diffusion, the concept of Critical Mass is linked to a minimal number of people who adopt an interactive innovation and this brings about an increasingly self-sustained rate of adoption in the future (Rogers, 2003). According to experts, clusters, or universities centres established for decades, are other illustrations of systems that continuously sustain a dynamic of research and innovation based on local interactions.

These objectives are not mutually exclusive, and then there may be overlaps, especially between "reaching excellence" and others. It could also be considered that "securing a certain level of competencies for "prospective reasons" is a prerequisite for "reaching a self-sustained dynamics" and *a fortiori* for "addressing socio-technological challenges". Alternatively, "securing a certain level of competencies for "defensive reasons" is only relevant when the scientific / technological field in question has already been largely developed. As already stated, the justification of these objectives is based on the insights gleaned from reviewing the literature, the experts and policy practice (EU STI policy). In the case of the latter, reaching Critical Mass is required to overcome fragmentation, dispersion and lack of coordination (at policy and R&D activities levels). Broadly speaking, the four selected objectives are all contributing to the overall objectives of EU policy (especially competitiveness). That said, in being defined at a scientific/technological level, they may be perceived to be located at different analytical levels of the "logic model" that shows the links between the sub-categories of EU policy objectives and EU objectives generally.

4 Critical Mass Analytical Framework

In this chapter, we present the Analytical Framework developed in this Study. The analytical framework is designed to help to provide answers to the basic questions the study raises:

- What is meant when it is said that public R&D programmes in Europe, in a particular S&T area, are individually and/or collectively achieving or not achieving Critical Mass?
- What are the determinants of the threshold of Critical Mass in a particular S&T area?
- In given fields, are the R&D programmes in Europe achieving Critical Mass?
- Why are public R&D programmes in Europe in those given fields reaching (or not reaching) Critical Mass?

4.1 Critical Mass definition and the analytical framework

The analytical framework is coherent with the definition of Critical Mass put forward in chapter 3 of this report. It also includes the factors (and the relationship between these) that explain why Critical Mass is reached, or not, and it is coherent with the metrics (indicators and measurement methods) set up to assess whether and why Critical Mass is achieved.

Critical Mass in R&D programmes has been defined as the threshold level of resources required during a certain period of time in order to achieve a certain type of objective, in particular:

- to address techno-scientific challenge, and/or
- to secure a certain level of competences for defensive or prospective reasons, and/or
- to reach excellence, and/or
- to reach self-sustained dynamics

Resources allow users to reach the objectives and R&D programmes are one key way to mobilize those resources. By definition then, Critical Mass is achieved when R&D programmes have managed to effectively mobilize sufficient resources to reach the objective. This relationship holds true, in that that the pooling of resources has been identified as the main contributory factor in reaching the objective. In certain contexts, it might also be possible to set the threshold level of resources through comparison, for example taking research areas outside the EU as a benchmark.

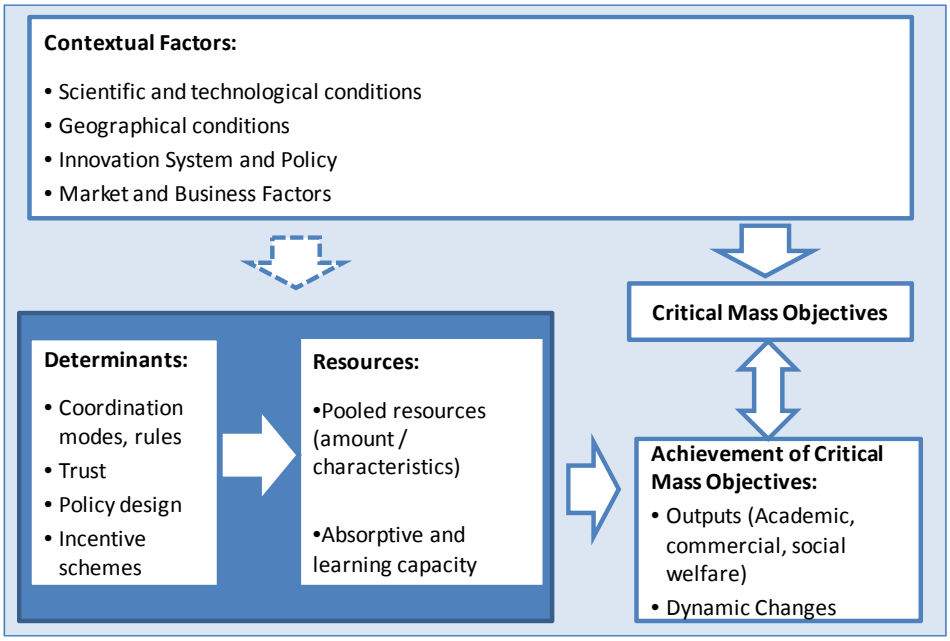
The analytical framework reflects the understanding of the present study with regard to the elements and relationships between elements (notably causal relations) that explains how achieving the objective corresponds to reaching Critical Mass. It can be described – as shown in Figure 4.1 – as follows:

- A public R&D programme is one of the means to mobilize resources. Never the less, resources alone are not sufficient to secure Critical Mass: they need to be pooled within certain conditions, part of which is policy driven. Enabling conditions (cf. contextual factors and determinants) are necessary and even “critical” for resources to reach Critical Mass.

These elements are not part of our definition, but they are important building blocks in our analytical framework.

- Research participants are carrying out R&D activities that are at least partly within the framework of R&D programmes. The research they are conducting, by pooling their resources together, then results in achieving the different objectives related to Critical Mass, or not.

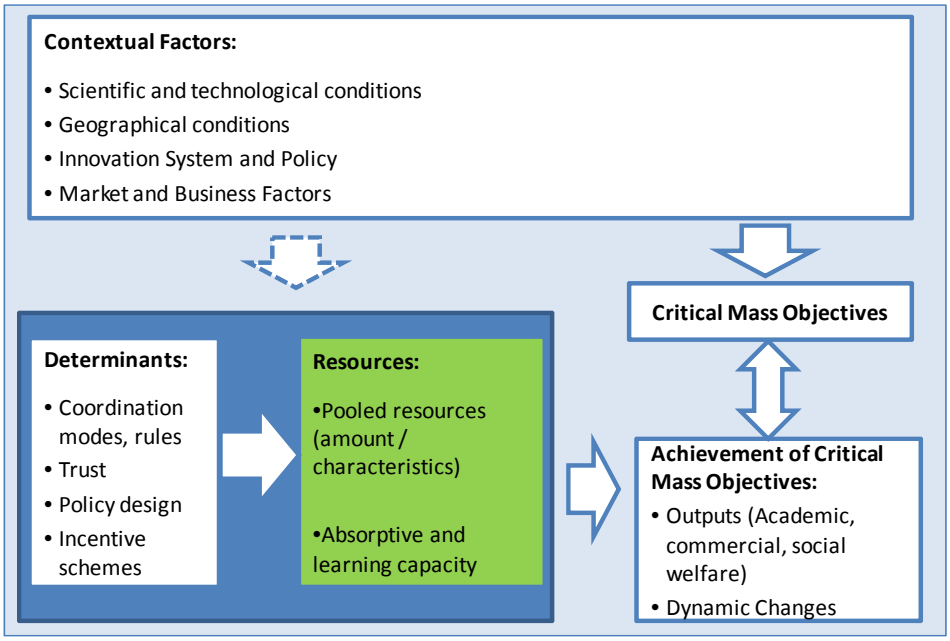
Figure 4.1 Critical Mass Analytical Framework and its dimensions



Different dimensions have a relative impact R&D policy and programmes, the way research is carried out and the appearance of research results that is linked to the Critical Mass objectives set. Some, in the design and implementation of R&D programmes, are policy driven whilst others are contextual, in the sense that they are related to the nature of the research fields in question and/or to the broader scope of the field of research in question. Besides Critical Mass objectives (described in Chapter 3) and how to achieve them, the elements individuated by the analytical framework are: resources, determinants and contextual factors.

4.1.1 Resources

Figure 4.2 Critical Mass Analytical Framework: resources



Pooled resources are the real components of the Critical Mass of research activities. What transforms then into Critical Mass is not only their ***characteristics*** (in terms of amount, quality, diversity, etc), but also their ***combination*** (how complementary they are, etc.) along with the ***absorptive and learning capacities*** of those providing or constituting these resources. Essentially, "resources" include every variant that there is whether human, physical (instrumentations, infrastructure etc), or financial, along with any /all knowledge and information (see Annex 1). In this study, these resources will be approximated by those conducting R&D activities (with regards to project level), and projects (with regards to programme level).

At project level, resources are combined for a precise research objective; at programme level, they are at work in separate projects, but their pooling should make it possible to generate synergies, secure the relevant coverage of a broader research area, avoid useless overlaps and sustain an appropriate level of competition between the projects. The basic rationale is that the larger the scope of resource providers, the larger the pool of resources the partners can draw on in order to achieve Critical Mass objectives.

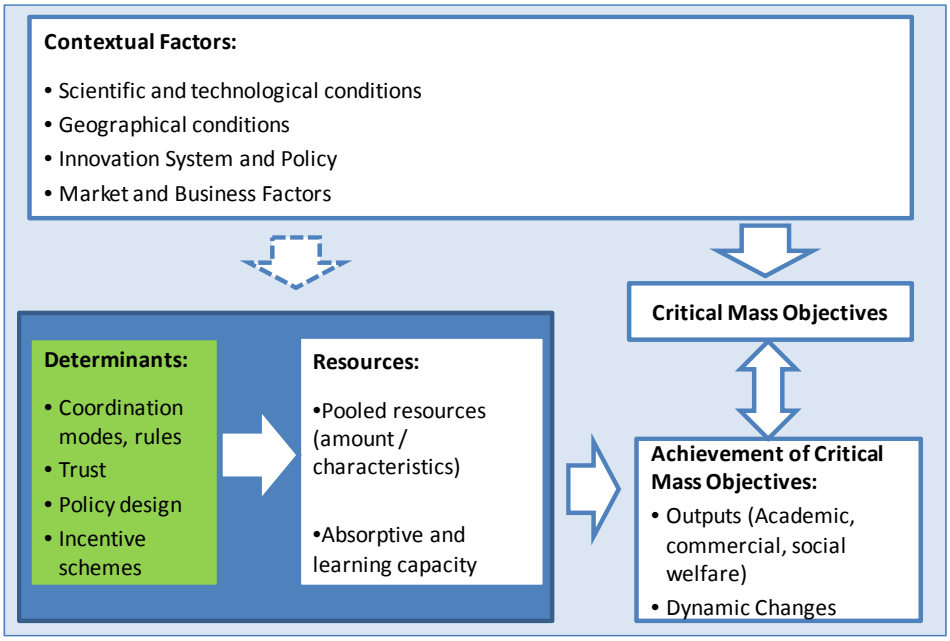
Critical Mass could therefore be the basic expression of the number of partners involved in a project/programme and/or the project/programme budget. There are trade-offs however that are very much related to S&T areas, such as geographical coverage, science networks, policies, funding strategies, involvement of industry and the private sector, and the scientific level of maturity.

At project level, a large consortium or a large budget would, in principle, significantly affect the project's internal (team) dynamics and be strongly associated with performance (Ancona & Caldwell, 1992; Jehn, 1995; Smith & Lipsky, 1994). In terms of both scientific and technological outputs, the efforts and skills of multiple (as opposed to just a few) partners in an R&D project would lead to a "larger" pool of resources and expertise, and hence would, "ceteris paribus", increase the likelihood for success (Schilling, 2005). Equally (if not more) important, a large consortium, composed of carefully chosen partners, would increase the heterogeneity of resources pooled together for project use. This connects with the notion of technological cognitive distance among project participants (Nooteboom et al, 2007). Increased heterogeneity in skills and experiences would foster creative problem solving and promote learning and new knowledge creation, therefore, ceteris paribus; it would increase the likelihood of project success.

Taken together, these effects would have a direct bearing on the consortium's absorptive capacity. The notion of ***absorptive capacity*** (ACAP) is important because it provides a way to conceptualize, specifically, the learning mechanisms that underlie the processes of exploration and exploitation. Building on the work of Cohen and Levinthal (1990), Zahra and George (2002) defined ACAP as the set of capabilities that relate to the acquisition, assimilation, transformation, and exploitation of knowledge to finally produce marketable innovative results. While the concept of ACAP was originally formulated to explain knowledge, creation and exploitation at company firm level, it has recently been extended to include inter-company relationships. For example, Lane et al., (2001) utilized the notion of ACAP at alliance level and found that the commercialization of research results was strongly related to the absorptive capacity of the alliance. This in turn was influenced by such factors as strategy, formal goals, trust and cultural compatibility between partners, and the degree to which partners' technological and market areas were related. The ACAP was also evident at a higher level, when the issue is not necessarily about exploiting knowledge to reach the marketplace, but the ability to exploit the knowledge assimilated in order to produce new useful scientific or technological knowledge is implicit. At programme level, Absorptive Capacity needs to be analysed for an entire research field/area, whereby Critical Mass is related to the amount of programme funding and the number of projects, researchers and organisations involved.

4.1.2 Determinants

Figure 4.3 Critical Mass Analytical Framework: determinants



On the one hand, the **determinants** correspond to the conditions that explain the level and characteristics of resources mobilized and their learning- absorptive capacities. Multidisciplinary projects, for instance, tend to favour the pooling of heterogeneous resources, large programmes tend to attract a large amount of resources, whilst targeting very advanced research topics that will attract top level researchers. On the other hand, they correspond to the conditions in which these resources are getting results. At the heart of the research activities, those conditions are "crystallized" in the level of ***coordination and trust*** achieved, but they depend on a whole range of parameters that characterize the boxes at the top of the chart above. For instance, grouping researchers who have already extensively worked together will favour trust between them. Imposing a well-defined but adaptable working structure will tend to favour the coordination of activities.

Apart from the positive effects of a larger and more heterogeneous pool of resources associated with large consortia, we also have to deal with the downside: the bigger the size, the higher the administrative and coordination costs of running the project. In addition, an “excessive” number of participants may bring a greater likelihood of social loafing and free riding, thereby decreasing the extent of learning (Gibson & Vermeulen, 2003; Wong, 2004) and hence the likelihood of project success. For example, Stuart (1998) argued that the most successful alliances are those between firms with similar technological focuses and/or operating in similar markets, whereas in contrast, distant firms find it difficult to cooperate effectively.

Nooteboom et al (2007) argue that Critical Mass at the project level, as reflected (primarily) by the consortium size and project budget, would exhibit an inverted-U shaped effect on the project's success through its effect on the consortium's absorptive capacity. That is, it would have a positive influence in permitting both a larger and more heterogeneous pool of skills and resources, and a negative effect in increasing the (broadly construed) administrative and coordination costs of running the project. At some stage, but it depends on the S&T area, the coordination, integration and networking costs could then well overcome the performance benefits. (In Nuclear Physics, international research groups of several thousand researchers are very common and effective. This might not be verifiable in all areas of science). The relative pay-off between the positive and negative effects will directly affect the consortium's absorptive capacity, and ultimately project success.

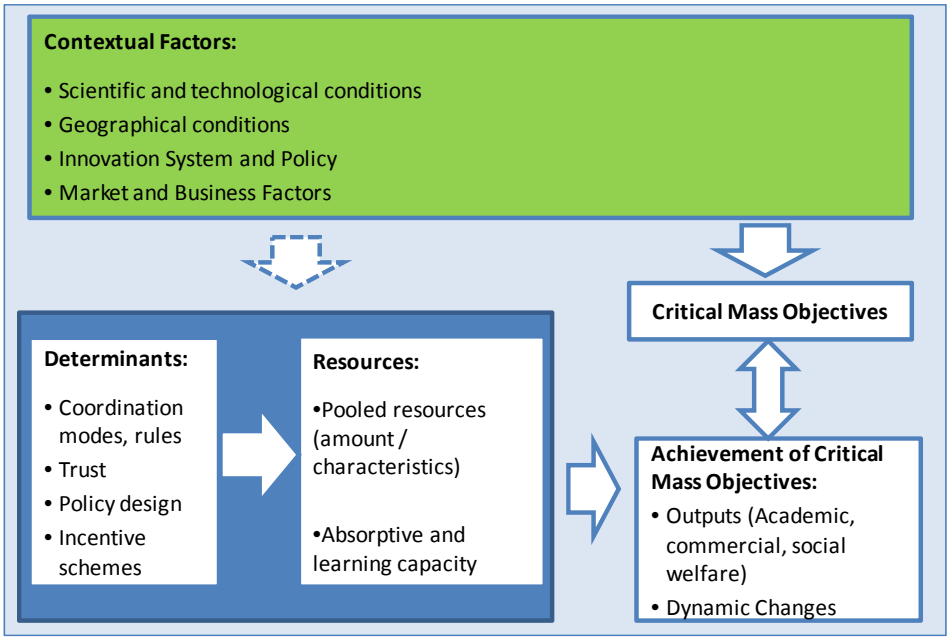
At a broader level, the issue of coordination (less related to trust) is also important, but it is related to the overall ***design of the programme***, and notably the architecture (in time and space) of the projects within a given programme, and the coherence in the architecture of projects across the different programmes.

Availability of resources and coordination/trust also depend on a series of different variables at different stages of R&D programmes. In the general case of R&D programmes broken down into R&D projects in which different research participants are grouped into consortia, these are:

- *The participants or beneficiaries of R&D programmes:* Certain characteristics (size, sector, nature, past experience, degree of commitment) may influence their capacity to provide resources and to exploit them
- *The consortium set up for the R&D programmes:* The composition of the consortium is key and can be considered from various perspectives: the size of the consortium, the relative number of partners, the diversity of partners and the distance between them culturally or geographically
- *The project characteristics* include variables related to the project itself (objectives, scope, degree of risk, cost, etc) and to how it is managed
- *The programme characteristics:* range from the size of the programme, the scope - in terms of its scientific, technical and / or sectorial focus - the architecture of projects adopted and how it inter-connects with other national and regional programmes

4.1.3 Contextual factors

Figure 4.4 Critical Mass Analytical Framework: contextual factors



From our perspective, **the contextual factors** that affect the achieving of Critical Mass are those that could explain: i) why a specific objective is assigned it and ii) why the determinants are different from one area to the other, or why the same determinants have a different impact on achieving Critical Mass. Contextual factors might affect the following dimensions:

- *Scientific/technological characteristics of the area*

These are probably the most important characteristics. They include, for instance, the level of maturity and the speed at which the area is developing, the degree to which it interacts with other areas (an open or a multi-disciplinary area), the degree of competition between researchers, the importance of any physical or intangible infrastructures required, the degree of intensity of highly specialized human resources and their availability, the nature of the research (oriented towards exploration and breakthrough or the systematic exploitation of avenues following a clear roadmap or agenda or research), etc.

Market/business aspects of economic activities related to the R&D's field of application. This includes for instance, the closeness of R&D activities to the market (in terms of products/process/service development), the degree of concentration on the markets by R&D users or the stability, dynamism or turbulence of the general environment

- *Characteristics related to factors relative to Geography, the National or Regional Innovation system and policy.*

There are many different aspects that feature here, for instance:

- the size of the country/region
- the complexity of the innovation system
- the importance of social issues in determining the priority of R&D policies
- the existence of collaboration between R&D actors and markets actors for instance through clusters
- the legal framework related to IPR
- the incentives to internationalize for national STI policy making

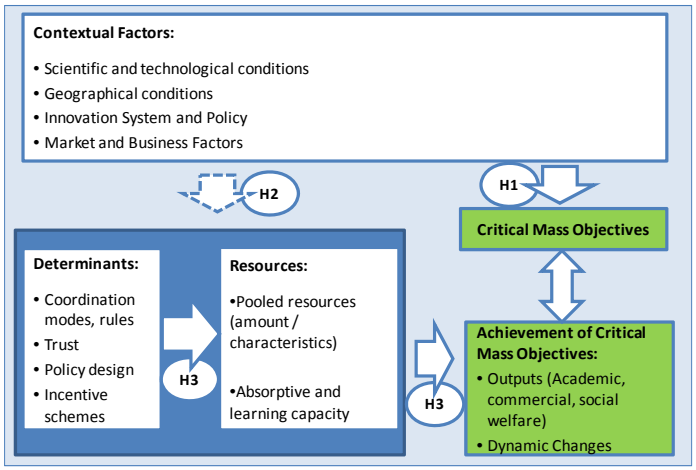
4.2 Critical Mass Analytical Framework and Hypotheses

In order to analytically link the dimensions of the Analytical Framework, a series of different hypotheses can be put forward as to how these links can be created which are shown in Figure 4.5.

Firstly, (**H1**) there are hypotheses about the way contextual factors lead to the determination of Critical Mass Objectives.

Secondly, they are hypotheses on the influence that contextual factors (**H2**) and determinants (**H3**) have on achieving Critical Mass and when pooled resources share come characteristics.

Figure 4.5 Analytical Framework: hypotheses



H1: What profiles of factors lead to the adoption of a specific Critical Mass objective?
H2: Which constraints are imposed by the factors as regards the determinants and the resources ?
H3: How will determinants allow to reach the Critical Mass of resources required to achieve the corresponding Critical Mass objective ?

4.2.1 Hypotheses on how characteristics of a field (contextual factors) affect Critical Mass objectives (H1)

A configuration of **contextual factors** (i.e. specific scientific/techno and geographical conditions, innovation systems, policy, and markets) will influence the type of objectives assigned in order to

reach Critical Mass. In other words, the objective linked to Critical Mass will depend on the environment in which the policy is implemented. Specific hypotheses could be put forward for all the different external conditions mentioned in our framework. Some hypotheses are summarized in table 4.1.

Table 4.1 Contextual Factors Determining Critical Mass Objectives

x=Characteristic is compatible to the field
X=Sufficient condition for determing the related CM objective

				Socio-technological challenge	Scientific challenge	Securing competence / defensive	Securing competence / prospective	Excellence	Self-sustained dynamics
S&T factors	Evolution of S&T area	Emerging		X	X		X	X	X
		Growing		X	X		X	X	X
		Mature		X	X	X		X	
		In Decline		X		X		X*	
	Connection to other research fields	Heavily connected		X	X		X	X	X
		Relatively independent			X	X	X	X	
Geographical factor	Worldwide Position in S&T area	Europe leading		X	X	X	X	X**	X
		Europe not leading		X	X	X	X	X	X
Market & Business factors	Connection to Market	Disconnected			X		X	X	X
		Future / Foreseeable Market		X	X		X	X	X
		Directly to Existing Market	Emerging	X				X	
			Launched & Fast-growi	X				X	
			Mature	X		X		X	
			In Decline	X		X		X*	
		Directly to Existing Market	Europe leading	X		X		X**	
			Europe not leading	X		X		X	

*Only if BOTH (Evolution of research field and stage of market) are "in decline", Excellence cannot be identified as an objective
**Only if Europe is in BOTH (S&T area and Market) "worldwide leading", Excellence cannot be identified as an objective

Hypotheses regarding Techno/scientific factors could be expressed as follows:

- In an emerging field, maintaining competencies for “prospective” reasons is a very relevant objective as these competencies could help address longer term future prospects, prospective socio-technological and scientific challenges, excellence and self-sustained dynamics
- In a growing field, maintaining competencies for “prospective” reasons, reaching a self-sustained dynamic, addressing socio-economic and scientific challenges and excellence are relevant objectives
- In a declining field, maintaining competencies for “defensive” reasons is a primary objective assigned to R&D activities, followed by socio-technological challenges

With regard to geographical factors:

- If Europe is a leading country in the specific S&T area, then all types of Critical Mass objectives are relevant, except reaching excellence (as Europe has already reached that level)
- If Europe is not a leading country in the specific S&T area, then all types of Critical Mass objectives are relevant

With regard to market/business factors:

- In a research field that has no market applications, Critical Mass objectives are most probably linked to scientific issues such as addressing a scientific challenge, reaching excellence, securing competencies for "prospective" reasons and self-sustained dynamics

With regard to the connection to other research fields:

- A research field, which is independent of other research areas (either as a user or supplier of their results) is not compatible with the objective of addressing socio-technological challenges nor with establishing self-sustained dynamics, whereas a strong connection is not compatible to the "defensive" Critical Mass type, as this applies to research fields that have a "stand alone" formed knowledge base

As regards the "sufficient conditions" in table 4.1, this means that securing competencies for prospective purposes in an objective for all emerging fields, regardless of whether other characteristics, as suggested by the table, are true. A field associated with an objective in this way, might of course be associated with other policy objectives.

4.2.2 Hypotheses on how contextual factors affect the determinants and resources needed for achieving Critical Mass (H2)

Contextual factors will have an influence on the relevance (or criticality) of some determinants for achieving Critical Mass, and on the "intensity" of the relations between the determinants and achieving Critical Mass. Indirectly then, these factors will support or hamper the achieving of Critical Mass.

Given the large range of contextual factors presented above, the possible effects can be extremely diverse and follow extremely varied patterns. This forces the scope of the analysis to be reduced as follows.

Some factors strongly determine the type of Critical Mass objective, as seen above. They cannot be included in the analysis in order to avoid an element of tautological reasoning. For example, in a highly emerging field, it is possible to define a Critical Mass objective such as "securing competencies for prospective purposes". In an emerging field, it is difficult to identify which

competencies/ players to secure, but doing so is a condition for reaching the objective of Critical Mass. If Europe is not a leading country, then "excellence" as a Critical Mass objective could be defined - “if Europe is not a leading country, making it so is the condition for reaching the objective of Critical Mass etc”. These factors are not therefore included here.

Numerous other factors are too contextual to be listed exhaustively (for instance the dependence on a very specific raw material for research, the necessity to associate a specific NGO, the commonality of a research issue for reasons related to geographical, climatic, social factors etc. Others are very general and are related to the existence of "good economic conditions", or "a coherent innovation system" and the like. These factors will not be included at this stage, but could be identified through specific case studies.

Finally, some of the factors are putting constraints on the determinants and resources, but without any strong direct relation to the nature of Critical Mass objectives. **These factors are prerequisites** that determinants and resources have to follow. Among them are the following:

- The need for specific instrumentation and research infrastructures: typically, in an area in which R&D does need large infrastructure because of the nature of the research, research infrastructure will be a key component of the Critical Mass
- A requirement for the geographical proximity of resources: this would imply the set up / involvement of a combination of resources situated locally, e.g. in the form of clusters
- A connection between the S&T fields and the market: if the connection is important, then industry should be associated; in an area where there is an oligopoly of large firms driving the research and innovation in the market, the determinants of Critical Mass will not necessarily be to attract the SMEs
- A connection between all the S&T fields involved: this will determine the profile (in terms of range of activities/links to other players) of the participants and beneficiaries.

Besides this, some political factors play a role, e.g. national interests can have a supporting or hampering effect on building Critical Mass or on the determinants relevant to building it

- In the case of the European Research Area, building Critical Mass at European level is dependent on the interest of national players. If they have similar interests and ideas on how to achieve Critical Mass at European level, these political motives help leverage the pooling of resources. If their motives are too different, this would clearly hamper any development. National interests are dependent on the overall size of the country and its research systems, the different structures of research and innovation systems, different political priorities and approaches to funding and the size and excellence of individual scientific communities
- A more particular example would be in fields with close connections to industry. A pooling of resources, which implies knowledge transfer, is something all market leaders are currently avoiding. IP regulations can have a hampering or supporting impact

4.2.3 Hypotheses on the link between determinants, resources and achieving Critical Mass (H3)

The determinants will have different impacts on achieving Critical Mass. More precisely, the determinants will positively or negatively affect:

- the level, nature and quality of resources available, i.e. **the pool of resources** available and their associated absorptive and learning capacities
- the way the resources are coordinated or combined, i.e. **the rules of coordination**, trust, and how complementary the resources are

Depending on the objective, a determinant may have more or less influence, greater or lesser impact on achieving Critical Mass; it may favour the achieving of the Critical Mass that corresponds to one objective and thwart the achievement of Critical Mass that corresponds to another objective.

4.3 The application of Critical Mass Analytical Framework to a specific programme

All the hypotheses put forward in the Analytical Framework, as well as the definition of Critical Mass and its various elements (resources, determinants, contextual factors), have been applied to a specific case. We refer to the ERA-NET scheme, which presents several characteristics pertinent to the analysis of Critical Mass: it is a public R&D programme; it implies coordination at international (EU) level and it makes it possible to gather good data. Before showing in detail(in chapter 6) how the Analytical Framework has been applied or Critical Mass measured, Chapter 5 provides a brief presentation of the ERA-NET scheme, the reasons it was selected for the Case Study and the process of data gathering throughout this study.

5 ERA-NET Case Study rationale

This chapter presents the approach for empirically testing the Critical Mass of public R&D programmes in accordance with the Analytical Framework developed in the previous chapter. Both the quantitative and qualitative analyses are based on the indicators presented in the Analytical Framework and derive from a review of the literature, interviews with experts and desk research.

Different methods were used to test these indicators. For some, a clear operationalisation is possible, and calculations for these were formulated in a quantitative way. For others, analysis must instead rely on a qualitative approach. Such indicators are in fact operationalised taking into account qualitative information collected both directly and indirectly.

In taking this approach, there were two main activities involved in the Case Study

- Development of an online questionnaire that for the most part, "translated" the indicators of the Analytical Framework indicators into research questions
- Vis-à-vis interviews, in which general discussions – and specific questions as well – followed the same structure as the online questionnaire, in order to build on the information already gleaned and when necessary, seek clarification of anything ambiguous

This two-level strategy has proven to be very effective: on the one hand, answers to the online questionnaire made it possible to measure Critical Mass, and on the other, when the results of the questionnaire were poor, further information gleaned from the interviews improved understanding.

5.1 The ERA-NET scheme for measuring Critical Mass

According to the Terms of Reference of the Critical Mass project, the Case Study had to focus on a selection of ERA-NETs (originally 10) from the 71 ERA-NETs funded under FP6. The ERA-NET scheme was launched as a complete novelty in 2002 under the Sixth Framework Programme (FP6 2002-2006). It was designed "to step up the cooperation and coordination of research activities carried out at national and regional level in the Member States and Associated States, through the networking of research programmes, including their mutual opening and the development of joint activities". As such, it constituted one element of the drive to create a European Research Area (ERA), helping in particular to restructure the fabric of research in Europe by means of the improved coordination of national and regional research activities and policies. The ERA-NET scheme constitutes a new approach to transnational research co-operation in Europe, one that enriches the Framework Programme and other European and International schemes, actions and initiatives.

By the end of the FP6, the ERA-NET scheme had culminated in 71 projects that covered many different fields of science and technology (S&T). The ERA-NET scheme led to 115 joint calls and 15 joint programmes involving, by the end of 2008, more than EUR 1.1 billion in joint funding, but it

also delivered a wealth of intangible results such as the establishment of new relationships and networks between funding organizations.

The aim of the ERA-NET scheme is “to develop and strengthen the coordination of national and regional research programmes through two specific actions:

- ‘ERA-NET actions’- providing a framework for participants to implement public research programmes and coordinate their activities e.g. by developing joint activities or by mutually supporting joint calls for trans-national proposals.
- 'ERA-NET Plus actions'- providing, in a limited number of cases with high European added value, additional EU financial support to facilitate joint calls for proposals between national and/or regional programmes.

Under the ERA-NET scheme, national and regional authorities identify research programmes for which there is a mutual desire to coordinate efforts or increase openness. Participants in these actions are therefore programme 'owners' (typically the ministries or regional authorities that define research programmes) or programme 'managers' (such as research councils or other research funding agencies that manage research programmes).

Cooperation between different partners of the innovation system is a crucial element of European R&D policy and it is tightly linked to the systemic failure mentioned at the beginning of this report. In other words, the analysis on achieving Critical Mass in the ERA-NET programmes will have to take into account analytical issues related to co-operation: trust, absorptive capacity, the pooling of complementary resources, learning ability, transaction costs and risk and cost sharing.

5.2 The adaptation of the Analytical Framework to the case of the ERA-NETs

The ERA-NET scheme has several features to which the Analytical Framework of chapter 4 (especially section 4.1) can easily be applied. A major specificity of ERA-NETs is that they include "participants", i.e. programme owners and programme managers involved in an ERA-NET, who represent countries and/or regions. The nature and composition of these participants and the possibility that they have past experiences in common, obviously has a strong influence on the design and implementation of the different activities, be they only coordination activities or activities more directly oriented towards R&D activities.

The participants were deemed to determinants of an intermediate level. Participants also conducted different types of activities that could be divided into two broad categories:

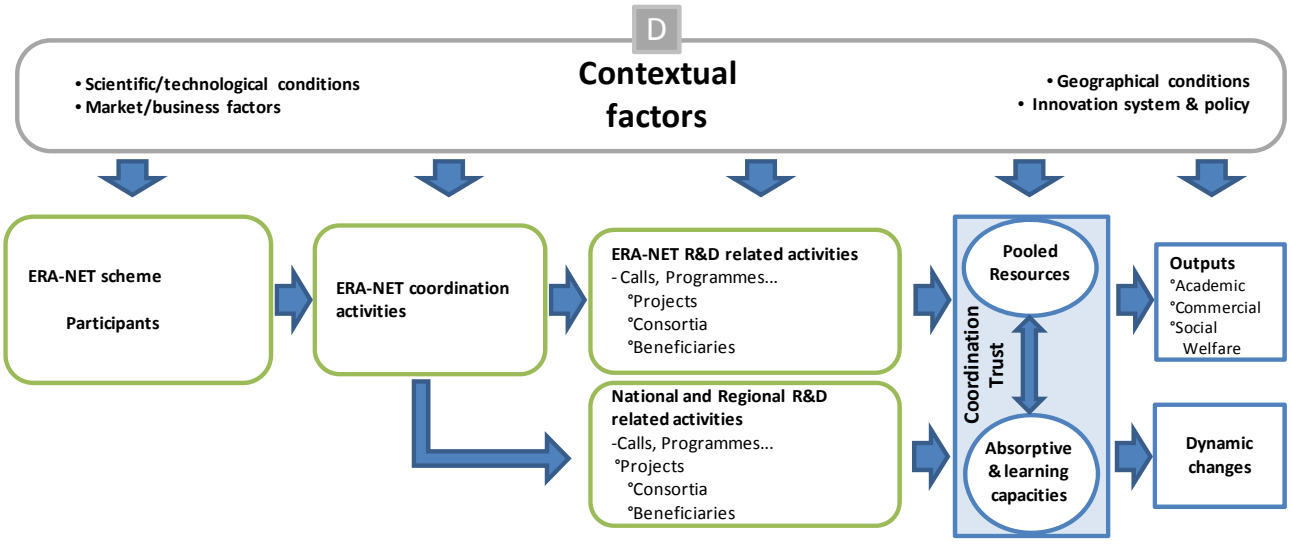
i) Activities that contributed to an increase in the knowledge participants acquired about each other and their programmes, the possible transfer of best practice protocols between them, and in more general terms, coordination between participants and their programmes. These activities

do not have a direct impact on those involved in research (labs, businesses etc), and are referred to in this study as "non-R&D activities"[4].

ii) activities that are directly related to the R&D activities of those involved in research (because they are funding it or providing the opportunity for it to be carried out), including joint calls, joint programmes, the mutual opening of infrastructures, and to some extent, training and mobilization activities for those involved in research.

These are to be seen separately from other programmes directly related to the R&D activities being carried out by the participants under the "umbrella" of an ERA-NET, although possibly on an international (typically bi-lateral) basis. The "coordination activities" carried out by the participants of an ERA-NET (see i) above), are helping to set up both types of activities directly related to R&D. The analytical framework presented in figure 4.5 can then be refined and made a bit more complex, as shown in figure 5.1 below.

Figure 5.1 Critical Mass Analytical Framework for the ERA-NET case



As figure 5.1 shows, the Critical Mass Analytical Framework makes it possible to explain how Critical Mass is achieved both individually (at the level of individual R&D programmes) and collectively (in terms of different EU R&D programmes that have been coordinated). In the empirical investigation of chapter 6 however, we focus on the latter. In fact, data gathered during the ERA-NET case study, through the online questionnaires and interviews provides a robust view of the collective achievement, which can be measured both through the different opinions on Critical Mass objectives (self-assessment) and operationalisating the output at the ERA-NET level. Diversely, achievements at the level of individual programmes would rely on self-assessment only,

[4] The survey question has included the following categories: (1) Coordination/clustering of ongoing nationally funded research projects, (2) Benchmarking and common schemes for programme monitoring and evaluation, (3) Multinational evaluation procedures (common evaluation criteria and methods of implementation), (4) Schemes for joint training activities (e.g. co-supervised theses or common PhD schemes), (5) Schemes for personnel exchange (programme managers), (6) Schemes for mutual opening of facilities or laboratories, (7) Specific cooperation agreements or arrangements between different ERA-NET partners have been made, and (8) Action plan taking up common strategic issues and preparing for joint activities.

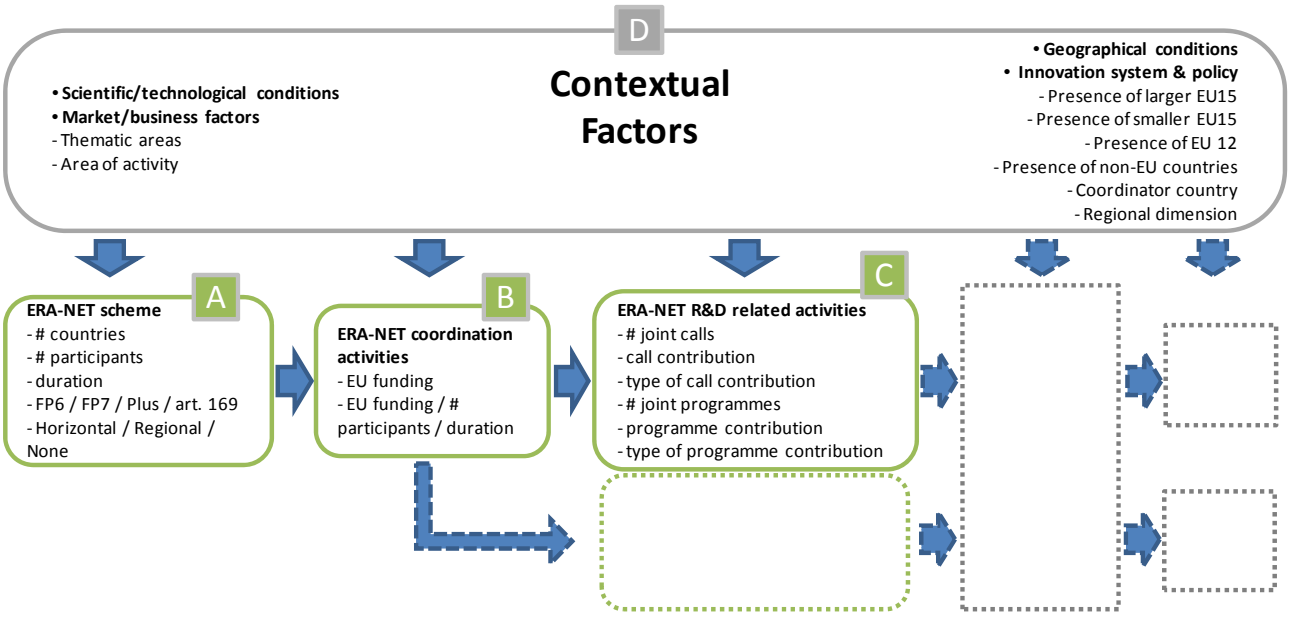
or would require the acquisition of data that was analogous to the collective case. In other words, data about the output of individual programmes (at national/ regional level), the beneficiaries and projects of these programmes, the determinants most likely to be influencing achieving Critical Mass at individual levels, and data about contextual factors relevant to individual programmes.

5.3 Choice of the ERA-NETs for Case study

In selecting ERA-NETs, the goal was to define an experimental context in which to test the level of achieving Critical Mass through the application of Analytical Framework. In identifying the ERA-NETs (originally 10, but increased to 13 during the project), their different thematic areas and other, specific features within ERA-NET schemes (i.e. ERA-NET+) were taken into account. Starting from the entire group of 71 ERA-NETs of FP6, attention was focused on those ERA-NETs that took advantage of the ERA-NET FP7, ERA-NET+ and article 169. This made it possible to carry out a broader analysis of the experiences of success and failure of FP6 ERA-NETs that had already concluded one step of their development and had begun the next one. By excluding from the case study list closed FP6 ERA-NETs that had not extended their activities under FP7, and applying selection criteria related to the analytical framework defined for the analysis of Critical Mass, 13 ERA-NETs were indentified for the case studies and for the online questionnaire.

The selection of the ERA-NETs who achieved Critical Mass and were therefore picked for the Case Study, began with the identification of variables related to the Analytical Framework, as shown in figure 5.1. It continued, following the process summarized in Figure 5.2, on the basis of variables available at the beginning of the project, therefore before the Critical Mass online questionnaire and interviews.

Figure 5.2 Critical Mass Analytical Framework and the selection of ERA-NETs



Among the variables taken into account for the selection, the most important, grouped by block variables are noted below:

A) ERA-NET Scheme:

- **Number of Countries** refers to the number of Countries participating to the ERA-NET[5]
- **Number of participants** refers to the number of research councils, funding agencies, ministries and/or public authorities participating in the ERA-NET[6]
- **Duration** refers to the duration of the ERA-NET programmes (up to 5 years)[7]
- **FP6/FP7/ERA-NET Plus/art.169**. This element identifies the regulation framework applicable to the ERA-NET in question. ERA-NETs falling into the **FP6** framework are those that started under FP6, and either ended at the close of the FP6 programme or that would be over by the end of 2010. The **FP7** ERA-NETs are those that began under the FP6 programme and continued during FP7. This type ERA-NETs can be distinguished from the others as they have a *"2"* or *"II"* after their FP6 name, showing that they would be continuing under the FP7 programme (e.g. ERA-NET Transport-II). **ERA-NET Plus actions**, are all those ERA-NETs started in FP6, who continued under FP7 and are willing to establish long-term collaboration between national research programmes. In addition, there are ERA-NETs that fall within the category of **Article 169** - joint calls and/or joint programmes that evolved into stable initiatives by progressing from an ERA-NET to an ERA-NET Plus initiative and on to full Article 169 initiatives. Two ERA-NETs in fact, completed this process, namely iMERA and BONUS[8]
- **National and regional ERA-NETs** are those that coordinate national/regional research programmes in accordance with the national or regional research priorities and strategies of an ERA-NET's participants. EU financial support incentivises the programmes to pool their resources to reach a higher level of integration, by stipulating agreed standards for the evaluation and selection of proposals[9]
- **Horizontal ERA-NETs**. The term *horizontal* refers to topics chosen by the ERA-NETs for their programmes and calls. ERA-NETs of a horizontal nature exist because they deal with joint programmes and/or joint calls that develop research topics identified in different Themes[10]

B) ERA-NET coordination activities:

- **EU funding** is intended in an absolute sense, namely the total amount of funds provided by the EU to each ERA-NET[11]

[5] The data have been collected from NETWATCH official website

[6] See note 5

[7] See note 5

[8] Data sources: DG Research, 2009, "FP6 ERA-NET Study - the Impact Assessment Study of the ERA-NET Scheme under the FP6" and NETWATCH website

[9] See ERA-NETs on stage – Annual event 2010 - The major event for research funding bodies in Europe; http://www.eranets-onstage2010.eu/docs/agenda.pdf

[10] Data sources: ERA-NETs on stage, DG Research data and NETWATCH website

- **EU funding per number of participants and per duration**: the amount of funding is divided per number of participants and per duration (up to 5 years). It is a relative measure to calculate the amount of funding on the basis of the number of participants and duration in order to better describe the coordination activities of an ERA-NET

C) ERA-NET R&D related activities:

- **Number of joint calls**, are the calls announced and launched by each ERA-NET[12]
- **Call contribution**: each participant of an ERA-NET provides part of their own funding. The call contribution is the total sum raised by all ERA-NET participants
- **Type of call contribution**: three types of call contribution can be identified[13]:
  - Real common pot: The national contribution of each Country participating in an ERA-NET is pooled and this "common pot" becomes the budget for that call, which is centrally administered. This provides funding for successful proposals, irrespective of the applicant's nationality and results in trans-national flows of funding
  - Virtual common pot: (aka distributed common pot) Countries and regions pay for their own participants, which does not involve trans-national flows of national funding. This mode of funding is the most frequently used option. This type of common pot does not actually establish a joint budget to finance the selected individual project, but is based on national/regional contributions. This call must be accompanied by national/regional calls. Each country funds the successful project partners in its own national project, and covers its own administrative costs
  - Mixed mode: This is a mix of the types of funding described above and is often used in ERA-NET plus actions
- **Number of joint programmes** refers to the programmes announced and launched by each ERA-NET[14]
- **Programme contribution** refers to the funding allocated for each programme announced by the different ERA-NETs. It is the sum of the contributions made by each participant in the programme.
- **Type of programme contribution**: ERA-NET programmes operate thanks to contributions collected in one of three ways: a real or virtual pot, or mixed mode

D) Contextual factors:

- **Thematic areas** refer to Industrial Technology and SMEs, Transport, Social Sciences and Humanities, Life Science, Environment, Fundamental Sciences, International Cooperation and Energy[15]

[11] See note 5

[12] Data provided by the DG Research of European Commission

[13] The data have been collected from NETWATCH official website

[14] Data provided by the DG Research of European Commission

- **Areas of activity** also described as *subsectors* refers to a specific thematic area, e.g. within the Environment sector. Sub-areas of activity refers to research in renewable energies, recycling programmes, programmes on limiting CO2 emissions[16]
- **Presence of larger EU15** refers to France, Germany, Italy, Spain and the United Kingdom.
- **Presence of smaller EU15** refers to Austria, Belgium, Denmark, Finland, Greece, Ireland, Luxemburg, the Netherlands, Portugal and Sweden
- **Presence of EU12,** refers to the newest EU Member States: Bulgaria, Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.
- **Presence of Associated Countries:** refers to non-EU countries that have special agreements with the EU. The Associated Countries are Switzerland, Norway, Iceland, Lichtenstein, Turkey, and Israel as well as the Associated Western Balkan Countries: Bosnia-Herzegovina, Albania, Croatia, FYROM, Montenegro and Serbia
- **Presence of third countries** refers to non-EU countries such as the USA, Japan, Canada, the Russian Federation etc.
- **Coordinator's country** Each ERA-NET has a coordinator who acts as its leader and Coordinator's country refers to its nationality

5.4 Criteria for the selection of ERA-NETs

In this section, we present the criteria used to select ERA-NETs.

5.4.1 First criterion: FP6 continuation

The first criterion for selection related to the continuation of FP6 activities. The ERA-NET scheme has been continued under FP7, due to the interest generated during FP6. Under FP7, the scheme has been strengthened, offering new tools such as ERA-NET Plus actions, where the Commission can provide – in a limited number of cases that have high European added value – additional financial support to facilitate joint calls for proposals between national and/or regional programmes.

The first set was composed by ERA-NETs in at least one of the following cases:

- FP6 ERA-NETs not closed by the end of 2010
- FP6 ERA-NETs continuing in FP7
- FP6 ERA-NETs that have become ERA-NETs Plus

Of the 71 ERA-NETs in FP6, there are 29 continuing activities in both FP6 and FP7

5.4.2 Second criterion: Comparison within thematic area

The next step was to select ERA-NETs with similar general characteristics, in which the primary rationale was a comparison of the sectors.

[15] Data sources: DG Research, 2009, "FP6 ERA-NET Study - the Impact Assessment Study of the ERA-NET Scheme under the FP6" and other DG Research data

[16] See note 5

In the *Rambøll report*[17], part of the analysis was made by grouping the ERA-NETs in *ex-post* 8 thematic areas:

1. Industrial Technologies and SMEs
2. Transport
3. Life Sciences
4. Environment
5. Fundamental Sciences
6. International Cooperation
7. Energy
8. Social Sciences and Humanities

This meant that thematic areas such as INCO and Energy fell away as areas to be compared because there was only one ERA-NET left in each sector. Similarly, Fundamental Sciences and SSH have only 2 ERA-NETs left, so the range within which to make a comparison is small. Taking these considerations into account, there are 23 remaining ERA-NETS. It is important to note that, for each thematic area left, **Environment (5), Industrial Technologies and SMEs (8), Life Sciences (7), and Transport (3),** it is still possible to effect comparison with at least one ERA-NET that will be active until 2010 and one ERA-NET that has continued under FP7 ("FP7 2" or ERA-NET Plus).
The selected ERA-NETs cover **four sectors**, which are **Environment (ENV), Industrial Technologies & SMEs (IND), Life Sciences (LS) and Transport (TR)**. An analysis of each thematic area, starting from the selection of one ERA-NET active until 2010 and an ERA-NET FP7 or ERA-NET Plus, was carried out, taking into account characteristics such as: the number of joint calls and contribution to funding; the number of joint programmes and the funding contribution; the number of participants; the number of countries; real Common pot vs. Virtual pot and Horizontal vs. Regional.

[17] DG Research, 2009, "FP6 ERA-NET Study - the Impact Assessment Study of the ERA-NET Scheme under the FP6", EUR 23909 EN, Luxembourg. The Rambøll Report is the study commissioned by the Directorate-General for Research of the European Commission on the impact assessment of the ERA-NET scheme, under the FP6. The report was issued in 2009, but was commissioned in April 2007 to Matrix Insight (www.matrixknowledge.com) to evaluate the impact of the ERA-NET scheme and related ERA-NET actions under the 6th Community Framework Programme for Research (FP6). Rambøll Management and independent experts supported Matrix Insight in delivering the impact assessment. The study focused on 71 ERA-NET coordination actions launched under the FP6 ERA-NET scheme in the 27 Member States of the European Union, Associated countries and Third countries over the FP6 period (i.e. 2002 – 2006).

5.4.3 The final set of ERA-NETs

After this analysis, a list of 13 ERA-NETs has been selected. Here follows a description with some details, starting from the referring data contained into the ERA-NETs Data Base.

Table 5.1 presents the list of selected ERA-NETs.

Table 5.1 Characteristics of the selected ERA-NETs

Sector	Acronym	Full name	Short description
Environment	BONUS	BONUS for the Baltic Sea Science - Network of Funding Agencies	It is focused on Marine Science. The coordinator country is Finland and the ERA-NET participants are coming prevalently from EU15. It is neither horizontal nor regional. The type of funding used is the Mixed Mode.
Environment	MARIFISH	Coordination of European Marine Fisheries Research	It focuses its research on fisheries resources. The coordinator country id United Kingdom and the majority of participants are coming from EU 15 smaller countries. It is a Horizontal ERA-NET.
Environment	NET-BIOME	NETworking tropical and subtropical Biodiversity research in OuterMost regions and territories of Europe in support of sustainable development	It analysed specifically the research area in biodiversity. The coordinator country is France and the majority of the participants are coming from EU 15 larger country. It is a regional ERA-NET.
Industrial Technologies and SMEs	IMERA	Implementing Metrology in the European Research Area	It focuses its research on metrology. The coordinator country is United Kingdom. There is a balance between presence of EU15 larger countries and presence of EU12. It is and horizontal ERA-NET.
Industrial Technologies and SMEs	MARTEC	ERA-NET Maritime Technologies	It is devoted to the shipping and marine engineering. The coordinator country is Germany and among the ERA-NET participants there is the same percentage (38,5%) of smaller and larger EU15 countries. It is a horizontal ERA-NET and the type of funding used is the Virtual pot.
Industrial Technologies and SMEs	MATERA	ERA-NET Materials	Its research is focused on materials science. The coordinator country is Finland. The presence of EU15 smaller country is the most relevant. MATERA used the Virtual pot type of funding. It has evolved in MATERA+.

Industrial Technologies and SMEs	MNT ERA-NET	MNT-ERA.NET From Micro- and Nanoscale Science To New Technologies for Europe	It deals with research fields such as Nanotechnology, micro-systems and micro-technology. The coordinator country is Austria and the presence of EU15 larger countries is 37,5%. It started in FP6 programme and continues in FP7, becoming MNT ERA_NETII.
Industrial Technologies and SMEs	MANUNET	Walking towards an European regionally based research area on new processes and flexible intelligent manufacturing systems	Its activities are focused on Transport research field. The coordinator country is Spain and the 50% of ERA-NET partners are coming from EU15 larger countries. The type of funding used has been the Virtual pot.
Life Science	ERASYSBIO	Towards a European Research Area for Systems Biology - A Transnational Funding Initiative to Support the Convergence of Life Sciences with Information Technology & Systems Sciences	Its research activities are focused on Computational biology, systems engineering, mathematics and informatics. The coordinator country is Germany and the majority of ERA-NETs participants are from EU15 Larger Countries. It has evolved into an ERA-NET plus actions.
Life Science	EUROTRANSBIO	EUROpean network of TRANS-national collaborative R&D for SME's projects in the field of BIOtechnology	Its research is focused on Biotechnology science. The coordinator country is France. The majority of participants are coming from EU15 larger countries. It is a horizontal ERA-NET which used the Virtual pot.
Life Science	NEURON	Network of European Funding for Neuroscience Research	Its research activities are focused on Neuroscience. The coordinator Country is Germany and 50% of ERA-NET participants are coming from EU15 larger countries.
Transport	AIRTN	Aeronautics ERA-NET as one of the key enablers of the prosperous development of Aeronautics in Europe	Its research activities are devoted to aeronautics. The coordinator country is Germany and 35,5% of ERA-NET participants are from EU15 larger countries.
Transport	ERA-NET ROAD	ERA-NET ROAD - Coordination and Implementation of Road Research in Europe	Its research activities are focused on Road and Traffic issues. The coordinator country is United Kingdom. The majority of ERA-NET participants are from EU15 smaller countries. This ERA-NET used the Common pot as type of funding.

5.5 Data collected from the selected ERA-NETs

As note previously, a two-level strategy was adopted in order to verify the appropriateness of the Analytical Framework and related indicators:

- The development of an online questionnaire, addressed to:
  - Selected FP6 ERA-NET Coordinators (Critical Mass survey S1-C)
  - Selected FP6 ERA-NET Participants (Critical Mass survey S1-P)
  - Selected Beneficiaries of FP6 ERA-NET projects (Critical Mass survey S2)
- Vis-à-vis interviews addressed to the Coordinators and Participants of 13 ERA-NETs

5.5.1 Critical Mass survey: results from ERA-NET Coordinators and Participants

With specific reference to questionnaires addressed to and interviews performed with ERA-NET Coordinators and Participants, the table below details, by section, whether indicators were tested by means of the questionnaire or discussion during interviews.

Table 5.2 Survey questions and interview topics[18], by section

Indicator section	S1-C	S1-P	Interview topics
1. ERA-NETs	4	4	Interview topic 1
2. Participants	8	7	Interview topic 1
3. and 4. Activities	29	14	Interview topics 2 and 3
5. ERA-NET projects	5	5	Interview topic 3
6. Non-ERA-NET projects	-	-	Interview topic 5
7. Outputs and Outcomes	5	5	Interview topic 4
8. Participant impact	-	-	Interview topic 4
9. Environmental conditions	12	-	Interview topics 1 and 5
Total	63	35	

The development of the online questionnaire required considerable effort, for two main reasons: firstly, because the indicators individuated had to be adapted to phrases that were immediately understandable to an online respondent and secondly, because there was no existing structured database contacts for FP6 ERA-NETs and this therefore had to be retrieved, mainly by desk research.

[18] Interview topic 1 has regarded: Strategic Considerations and Approach to R&D environment – Role of ERA-NET; interview topic 2: Overview of the activities carried out by this ERA-NET; interview topic 3: Focus on the main joint transnational activities specifically oriented towards R&D; interview topic 4: Selected joint calls / programmes: Results and Impacts; interview topic 5: Other impacts of this ERA-NET and overall assessment of this ERA-NET experience.

The main steps for the development of the S1-C and S1-P online questionnaire were as follows:

- Adaptation of indicators for the online questionnaire – August/September 2010
- Desk research for the individuation of contact details for Coordinators and Participants of 52 ERA-NETs (i.e. all the ERA-NETs in the 4 selected sectors: Environment, Life Science, Industrial Technologies and SMEs, Transport) – September 2010
- Pilot interviews to test the questions developed for the online survey – October 2010
- Physical letters sent to the people identified (830 contacts, in terms of ERA-NET/organisation) – November 2010
- Opening of the online survey on the 15th November 2010
- Survey data collected in the period: 15th November 2010 – 31st January 2011
- Email reminders to participants not registered – December 2010
- Further dynamic improvement of the contact DB and phone reminders for registered users that had not yet responded – February/March 2011
- Final version of Critical Mass database – April 2011

The following tables summarize the results in terms of registered users and respondents[19]. Coordinators and Participants are grouped in two different tables. In each table, respondents are then grouped by type of ERA-NET (Case Study vs. Non-Case Study ones).

Table 5.3 Respondents to Coordinator and Participant surveys by ERA-NET type

	Coordinators	Participants	Total
13 Case Study ERA-NETs total	13	55	68
Population (13 ERA-NETs)	13	231	244
Response Rates	100%	24%	28%
Other 39 ERA-NETs	11	69	80
Population (39 ERA-NETs)	39	547	586
Response rates	28%	13%	14%
Total	24	124	148
Population (52 ERA-NETs)	52	778	830
Response rates	46%	16%	18%

[19] In terms of survey strategy, the first step has been that of contacting the reference persons of each ERA-NET by physical letter. After few days, already several registered users had retrieved their credentials on the website (at http://register.criticalmassproject.eu). The strategy of asking them to register first and only successively giving them access to the online survey has allowed to double-check them carefully. Misspellings as well as mistakes in the registrations (Participants registering as Coordinators; old/new organisation affiliations etc.) have been corrected since the beginning.

Table 5.4 Respondents to Coordinator and Participant surveys by sector

FP6 ERA-NETs	Sector	Coordinators	Participant	Total
16	Environment	6	24	30
16	Industrial Technologies and SMEs	10	55	65
16	Life Sciences	6	31	37
4	Transport	2	14	16

As expected, there was a particularly high response from the ERA-NETs in the case study. All 13 Coordinators responded to the online survey, as did 24% of Participants from those same 13 ERA-NETs. That percentage represents a number higher than the Participants interviewed, showing that contacting the 13 ERA-NET Coordinators made it possible to stimulate greater interest in the questionnaire, even amongst those contacts that have were not involved in the interviews.

When looking at the respondents' characteristics, the following features can be highlighted. As shown in the figures below, Participants that responded to the questionnaire are evenly distributed amongst the bodies that finance research activities, those that only manage them and others that are responsible for both financing and managing. Diversely, there is a high concentration of respondents in the category of bodies funded exclusively from public sources.

Figure 5.3 Distribution of respondents by organisation type

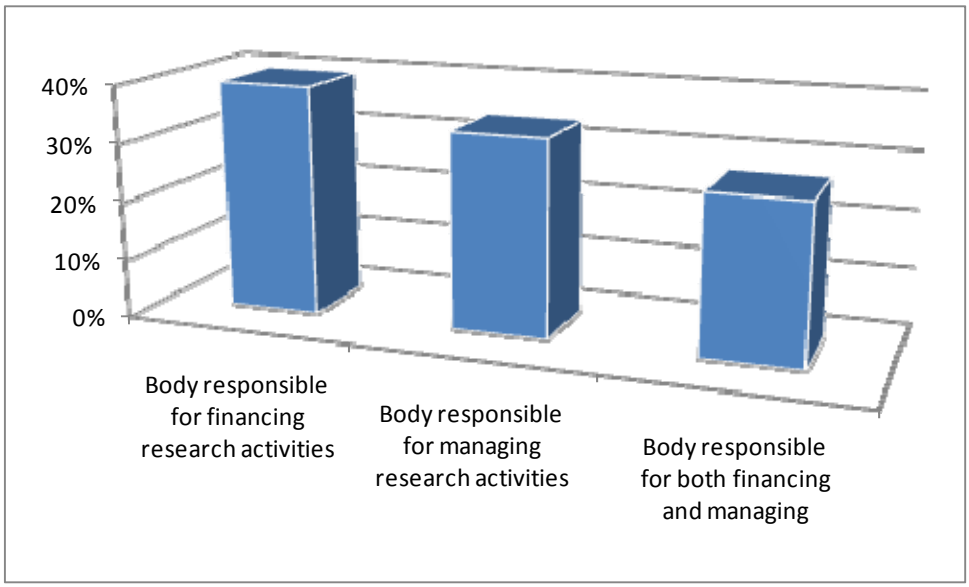
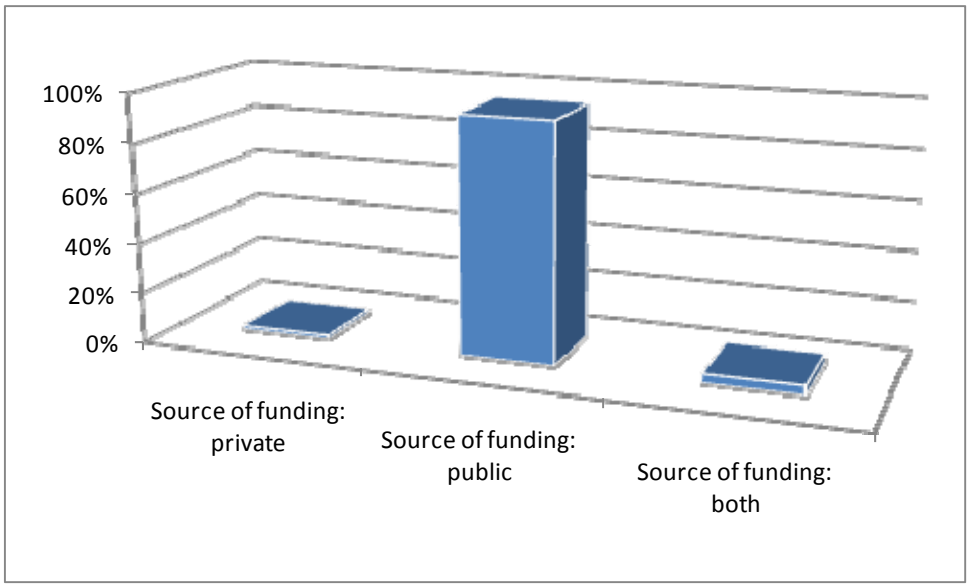
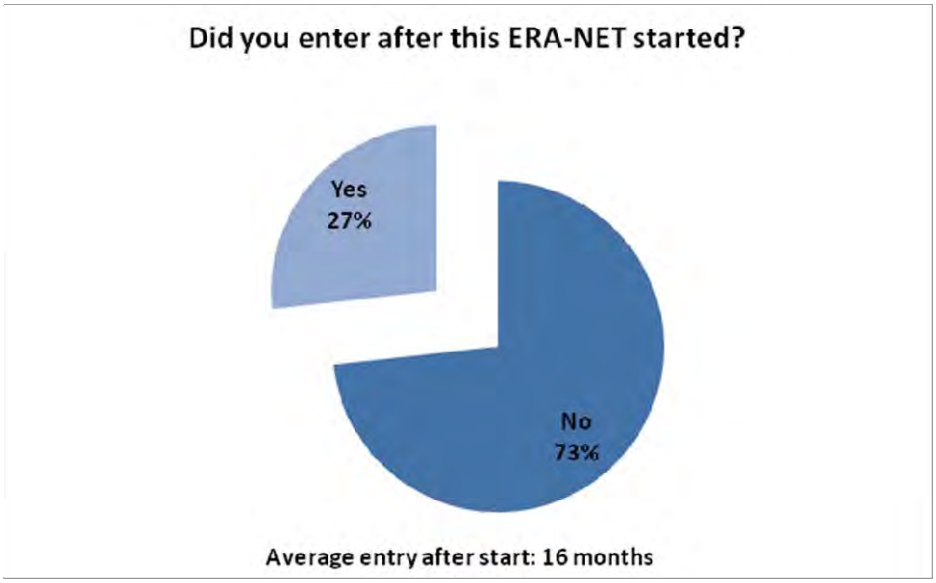


Figure 5.4 Distribution of respondents by source of funding



Almost three quarters of respondents therefore, have been participating in their ERA-NET since the very beginning. Only 27% joined after the ERA-NET had started and on average, this was 16 months later.

Figure 5.5 Percentage of participants entering after the ERA-NET start



In order to understand the respondents' motivation for participating in an ERA-NET better, we asked them about their individual motivation. Among the motives presented in the table below, the first three and the second three can be considered to be of comparable quality. Motives such as "Learning", "Benchmarking" and "Networking" imply better orientation and information at international level, but no commitment to joint activities as yet, whereas "Improving own programmes", "Creating new opportunities for research cooperation" and "Opening up of

programmes" are more likely to imply an commitment of national resources to joint international activities. The first group of motives can be regarded as a prerequisite for closer collaboration as implied by the second group of motives.

As to the main reasons for participating in an ERA-NET (set as a multiple choice question), the answers "transnational networking" and "creating new opportunities for research cooperation" were selected most. This means that there is enormous interest among participants in joint activities, but there is a comparably large need seen by many respondents to first form the basis for such collaboration. In any case, there is only a minimal difference between the preferences expressed by Coordinators and Participants, as detailed in the table below.

Table 5.5 Responses to the "main rationale" question

Main rationale for participating in the ERA-NET (multiple choice possible)	Coordinators	Participants
Learning from funders and sharing information between funders in other countries	12	52
Benchmarking of research funding against other countries	2	26
Networking and building new relationships with funders from other countries	**19**	**82**
Improving own (national) R&D programmes	6	50
Creating and supporting transnational projects in a field which requires transnational cooperation	**21**	**75**
Opening up of national programmes in existing or new areas of research	7	29
Other	2	2

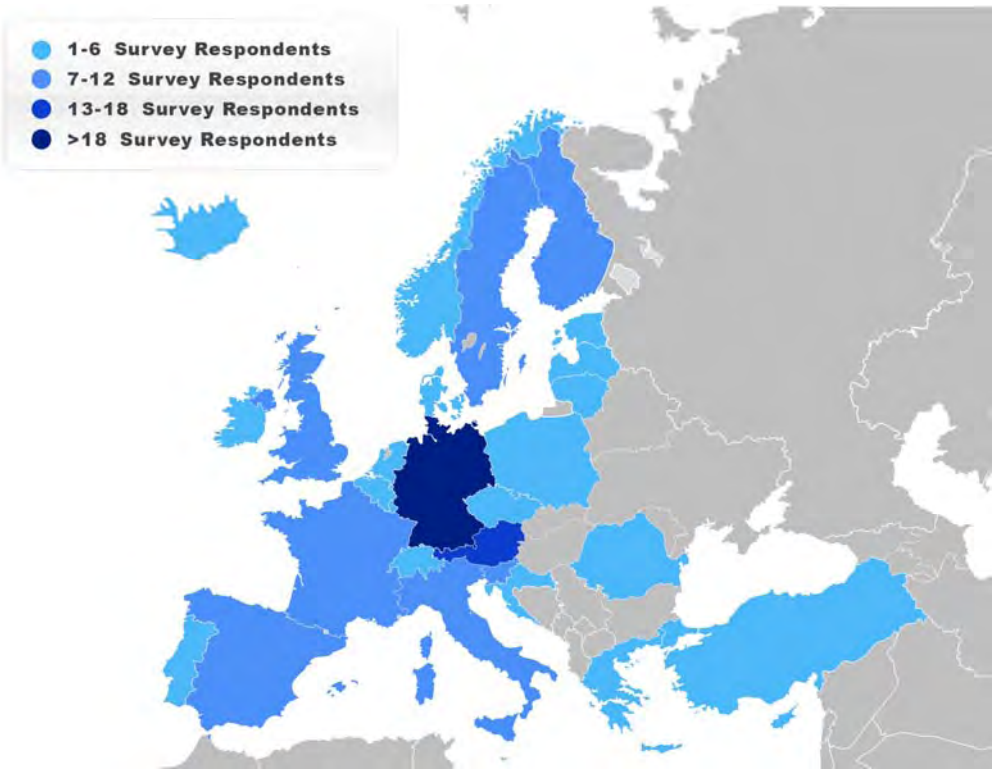
In terms of activities undertaken by ERA-NET coordinators and participants, an overview of the Joint Calls is shown in the table below.

Table 5.6 Overview on respondents' Joint Calls activity

ERA-NET Joint Calls assessment by respondents	
Respondents participating to ERA-NET Joint Calls	82
Respondents NOT participating to ERA-NET Joint Calls	29
Respondents considering ERA-NET Joint Calls as much more complex than national calls	40
Respondents considering ERA-NET Joint Calls as NOT much more complex than national calls	55

Finally, in terms of the respondents' geographical location, figure 5.6 shows the response rates for all European countries.

Figure 5.6 Survey respondents by country



5.5.2 Critical Mass survey: questionnaires addressed to Beneficiaries of ERA-NET projects

The last set of players, who answered a different online questionnaire, were the Beneficiaries of ERA-NET projects. As already described in the methodological section, as there was no comprehensive list of such beneficiaries, it was extremely difficult to contact them. Most contacts for Beneficiaries were found through desk research and the help of a few ERA-NET Coordinators and Participants able to provide the necessary information. In many cases, in fact, the limitations faced was not the unwillingness of ERA-NET Coordinators and Participants to provide Beneficiary contact details, but the impossibility of doing so for confidentiality reasons. In other cases, it was surprising to discover that some ERA-NET Coordinators and Participants do not even possess this information. This point is made again in Chapter 8 and is clearly something that must be improved.

The project steps undertaken for to develop a database of Beneficiaries were as follows:

- Adaptation of indicators for a questionnaire for Beneficiaries – October 2010
- Desk research and interviews with Coordinators/Participants' interviews to determine the contact details of the Beneficiaries of 52 ERA-NETs (in the 4 selected sectors: Environment, Life Science, Industrial Technologies and SMEs and Transport) – November/December 2010
- Pilot interview to test questionnaire – November 2010
- Email sent to the people identified (500 contacts) – January 2011
- Launch of the online questionnaire – January 2011
- Questionnaire data collected in the period: January / April 2011
- Final information on respondents:
  - 25 registered users
  - 9 respondents

Due to the low number of respondents, a decision was made not to use the results of Critical Mass survey S2 for the analysis. In any event, this problem had been anticipated right at the beginning of the project and the difficulties encountered simply confirmed expectations.

5.5.3 Critical Mass Case Study vis-à-vis interviews

The information gathered through the online survey has made it possible to form a broad view of Critical Mass in the ERA-NET scheme. As with any online questionnaire however, a fully comprehensive picture of all some topics was not expected, as more in-depth knowledge can only be obtained by other means. This refers to the vis-à-vis interviews that were planned at the start of the project, aimed specifically at having direct contact with those responsible for public R&D programmes. In almost all cases, the interviews were performed at the interviewees' premises, and only very few (less than 10%) were carried out on the telephone call or video-conferencing.

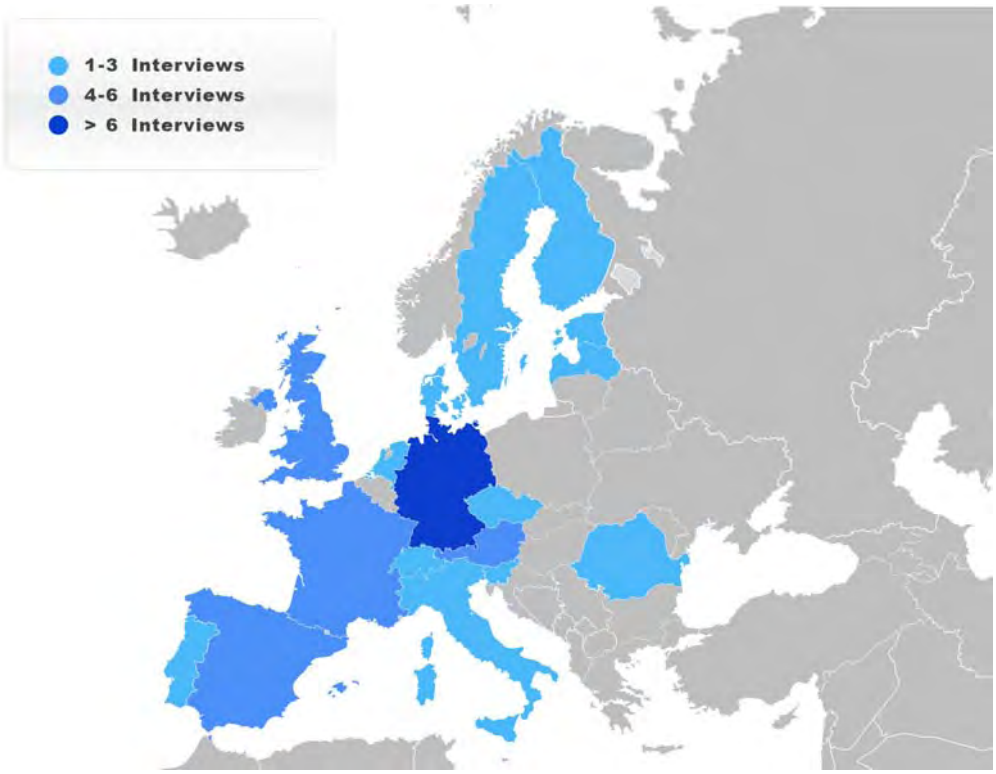
The first set of interviews were regarded as a pilot exercise: three interviews – one with an ERA-NET Coordinator and two with ERA-NET Participants – were conducted in order to assess and improve the questions in both the online questionnaire and the interviews themselves. The full round of interviews began after that and continued until the total number of interviews planned for the project had been completed.

The timing of vis-à-vis interviews was as follows:

- Adaptation of indicators for vis-à-vis interviews – September 2010
- Desk research to identify the ERA-NETs for pilot interviews – September 2010
- Three Pilot interviews (one with an ERA-NET Coordinator and two with ERA-NET Participants) to test the questions developed for both the online questionnaire survey and the actual interviews – October 2010
- Another 45 vis-à-vis interviews with ERA-NET Coordinators and Participants – November 2010 / January 2011
- Analysis of interview results for the Case Study Report – November 2010 / January 2011

The interview plan has made it possible to cover much of Europe. Countries with a very different approach to public R&D programmes were involved in the interviews, which means analysis of the Case Study benefited from extensive information. The interviewees were selected to complement, the information gleaned from the online questionnaire, and their geographic location was also a factor. A few refusals to be interview were received, but mostly because the person contacted was simply unavailable during the interview period. It was rare that people refused point blank to be interviewed. The figure below represents a summary of the countries involved in the interviews or to which interviewees belong.

Figure 5.7 Interviewees by country



The plan was to take a cross-country and cross-sector approach, which meant that whenever possible, the interviews with subjects were not concentrated in the same country and sector. A good balance of ERA-NET Coordinators / Participants operating at national rather than regional level was also achieved.

The figures that follow present an overview of the countries to which interviewees and those who answered the questionnaire belong, for each ERA-NET sector (Environment, Industrial Technologies and SMEs, Life Science, Transport).

Figure 5.8 Survey respondents and interviewees: Transport sector



Figure 5.9 Survey respondents and interviewees: Life Sciences sector

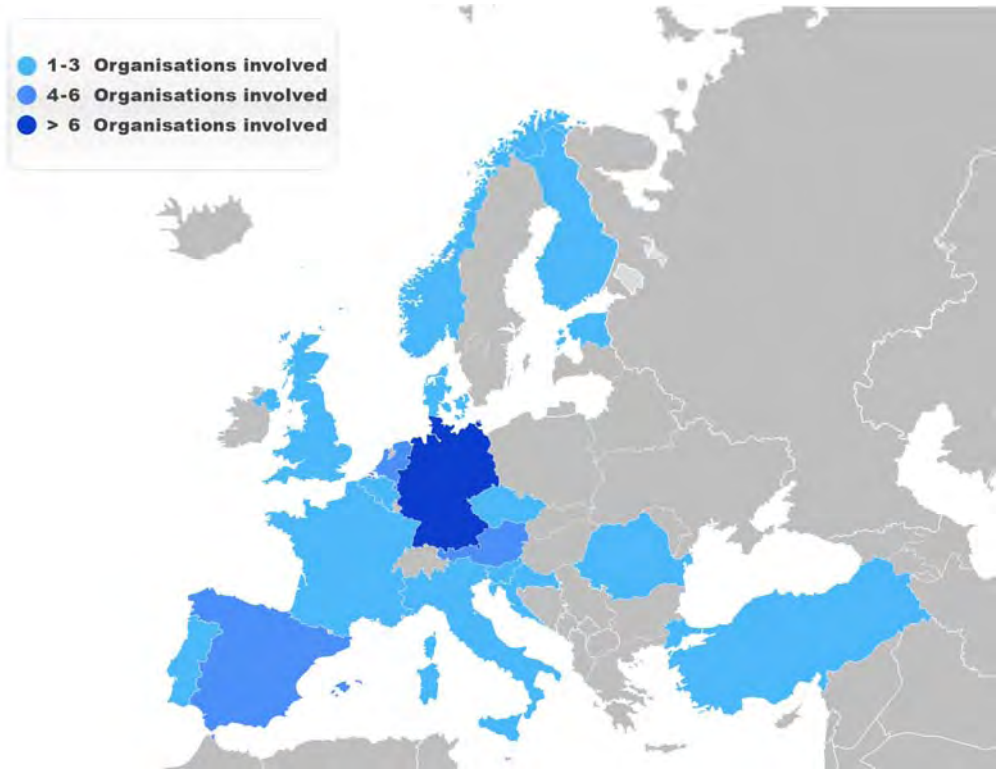


Figure 5.10 Survey respondents and interviewees: Industrial Technologies and SMEs sector

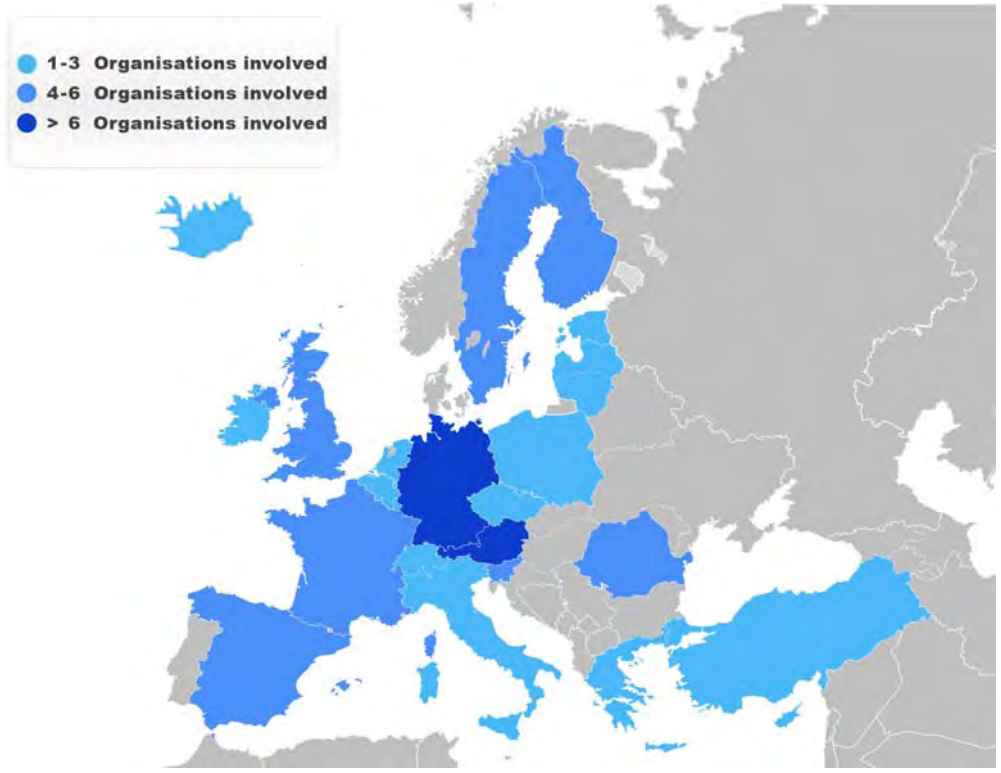
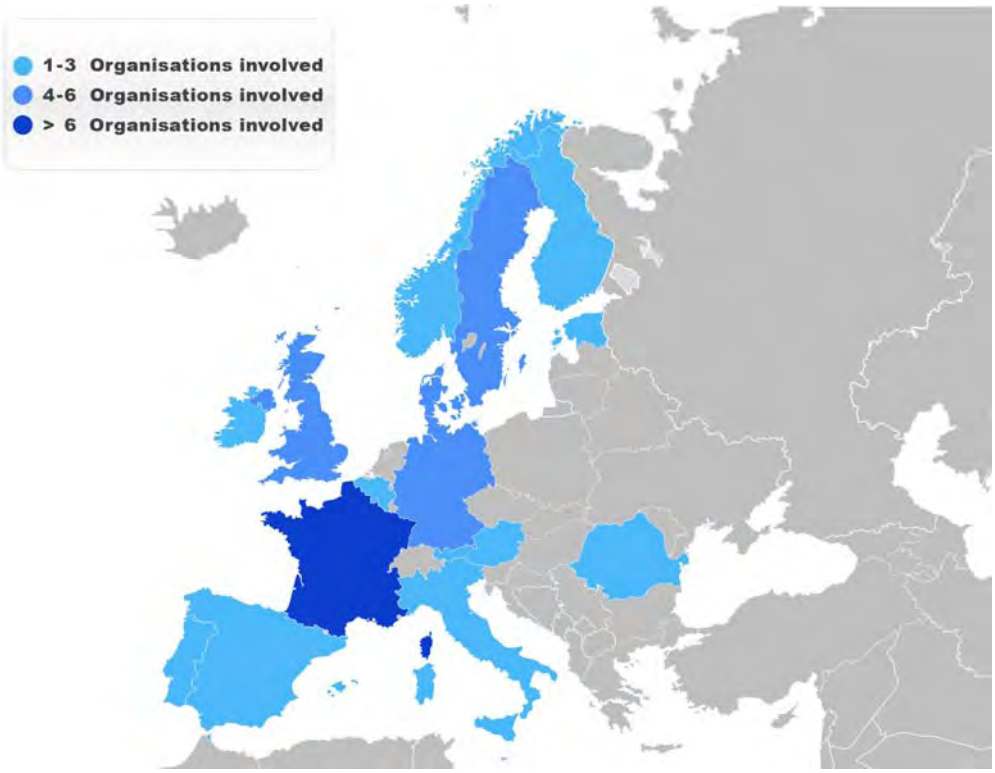


Figure 5.11 Survey respondents and interviewees: Environment sector



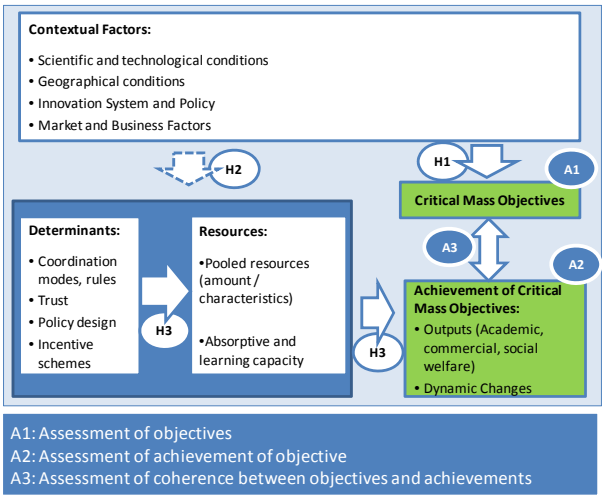
6 Critical Mass measurement through the ERA-NET Case Study

This chapter presents the operationalisation put in place to measure Critical Mass for the ERA-NET Case Study. As anticipated in section 5.3, in the specific case of ERA-NETs, the general Analytical Framework had to be adapted. This particularly concerned the role of "participants", i.e. programme owners and programme managers involved in the ERA-NET, as the countries and/or regions they represented were also a part of the picture.

This in turn meant that in adapting the hypothesis to ERA-NETs, more detailed explanations had to be provided, especially with regards to H3 and that made it possible to design and then follow a rigorous and logical sequence of methodological steps for the evaluation process.

6.1 The adaptation of hypotheses to the case of ERA-NETs

Figure 6.1 Analytical Framework in the ERA-NET case



The general hypotheses put forward in chapter 4 was further developed so that it could be tested through an ERA-NET Case Study. In figure 6.1 below, the linking of the different elements of the Analytical Framework reflects the peculiarities of the ERA-NET scheme. In addition to assessing the hypotheses, three other assessments were carried out:

A1) Assessment of objectives (i.e. the Critical Mass objectives for each ERA-NET)

A2) Assessment of achievement of objectives (empirically based)

A3) Assessment of coherence between ERA-NET objectives and their achievement

To summarise the hypotheses in brief:

H1) That the configuration of **contextual factors** (i.e. specific scientific/techno and geographical conditions, innovation systems, policy, and markets) influences the type of objectives assigned to reach Critical Mass

H2) That contextual factors influence/constrain the **determinants** and **resources** needed for achieving Critical Mass

H3) That there is a link between determinants, resources and the achievement of Critical Mass.

Whereas hypotheses H1 and H2 did not need to be re-formulated for the ERA-NET application, H3, as described in the next section, did

6.1.1 The link between determinants, resources and achievement in the specific case of ERA-NETs

In the case of ERA-NETs, in general terms, determinants are classified according to the type of influence they have:

- a positive impact on the pool of resources available
- a positive impact on coordination issues;
- a positive impact on the pool of resources available (i.e. therefore a positive influence on the likelihood of reaching Critical Mass) that is **combined with** a negative impact on coordination issues (i.e. which hinders the likelihood of reaching Critical Mass).

In particular, table 6.1 summarizes the effect of these influences on the main hypotheses as pertinent to ERA-NETs. This table takes into account the specificities and the complexity of the design of ERA-NET programmes, but can also be adapted to the more general instruments used in Framework Programmes. For instance, in the latter, the following elements are most probably not relevant: the participants; coordination activities and ERA-NET management quality. All other elements in the chart should be relevant to "classic" FP instruments. Note that the beneficiaries correspond to players in the R&D projects.

In the table, some determinants (highlighted in light blue) have a positive impact on the pool of resources. Those determinants are:

- The quality of the selection of projects and beneficiaries is linked to all objectives
- The duration of the project is linked to securing competencies and reaching self-sustained dynamics

Typically, some other determinants (highlighted in green) have a positive impact on the coordination. Those determinants are:

- Previous links or cooperation between beneficiaries is associated with socio-technological and scientific challenges and to self-sustained dynamics

- The existence of complementary R&D actions is linked to all objectives except securing competencies

Table 6.1 Relation between Determinants, Resources and Critical Mass Objectives in the ERA-NET case

X: Important determinant X: Determinant playing a role (X): Possible determinant	Socio-technological challenge	Scientific challenge	Securing competence / defensive	Securing competence / prospective	Excellence	Self-sustained dynamics
Participants						
number	**X**	X	(X)	(X)	(X)	**X**
diversity	**X**					X
previous links / cooperation between participants	X		X	X		X
Programmes						
coherence with national / regional programmes	X		X	X		X
calls: number	X	X			(X)	**X**
calls: amount of money	X	X	X	X	**X**	X
calls: quality of selection of the projects / beneficiaries	X	X	X	X	X	X
calls: participants involvement	X					X
calls: industry involvement	**X**		X			(X)
existence of complementary R&D actions	X	X			X	X
coordination activities	X					X
quality of ERA-NET management	X					X
Projects						
number of projects	(X)	X			(X)	X
amount of money for projects	X	X	X	X	**X**	X
duration of projects			X	X		X
novelty of anticipated results		X		X	X	
orientation towards development	**X**					
diversity of projects	**X**	X				**X**
Beneficiaries						
number of beneficiaries	X	X			(X)	**X**
quality of beneficiaries	X	X	X	X	**X**	X
diversity of beneficiaries	**X**	X				**X**
previous links / cooperation between beneficiaries	X	X				X

RELATION TO CRITICAL MASS ACHIEVEMENTS:	
Positive relation with pooling resources, negative relation to coordination	+ / -
Positive relation with pooling resources	+
Positive relation with coordination	+

Finally, the majority of determinants (highlighted in dark blue) have a positive impact on the pool of resources available **and** a negative impact on coordination issues. For ERA-NETs, these determinants concern the participants, programmes, the project itself and the beneficiaries; for more classical FP instruments there are usually no participants and only R&D activities. The

determinants are linked to some objectives but not necessarily to all. Some of the hypotheses could be formulated as follows:

Participants

- the number of participants (an increasing number of participants will increase the possibility of pooling resources at their lowest level and with it, the possibility of reaching Critical Mass, but it will have a negative impact on coordination and therefore also the possibility of reaching Critical Mass). This determinant is linked to all four objectives but with varying significance. Addressing socio-technological and scientific challenges and reaching self-sustained dynamics are the most important objectives, while securing competencies and reaching excellence are more marginal
- the diversity of participants (in terms of country, type of organizations, size etc.) is linked to socio-technological challenges and self-sustained dynamics

Activities

- the number of calls is mainly linked to self-sustained dynamics and to a lesser extent to socio-technological and scientific challenges and only marginally to reaching scientific excellence
- the amount of financial resources for calls is linked to all objectives

Projects

- the number of projects is linked to scientific challenge and self-sustained dynamics
- the amount of financial resources of projects is linked to all objectives
- the diversity of projects (in terms of size, amount of money, etc.) is linked to addressing socio-technological challenges and self-sustained dynamics. Typically the diversity of projects will either not be a determinant in securing competencies or it will have a negative impact on the pooling of resources. Securing competencies is more related to the specialization of resources than to their diversity

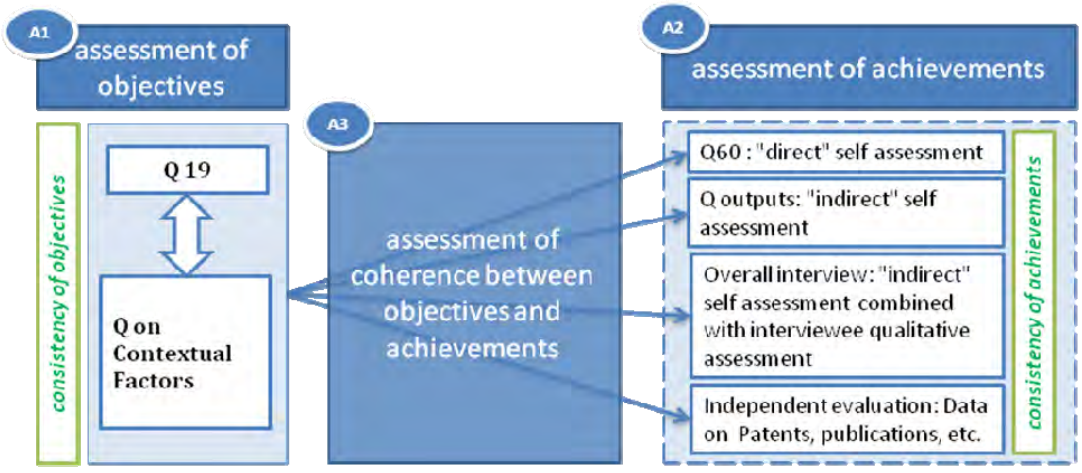
Beneficiaries

- the number of beneficiaries is primarily linked to reaching self-sustained dynamics
- the quality of beneficiaries (absorptive capacity, learning ability, leading position on market etc.) is linked to all objectives but chiefly to reaching excellence
- the diversity of beneficiaries (in terms of size, country, sector, type of organization etc.) is linked to addressing socio-technological challenges and to a lesser extent to scientific challenges and self-sustained dynamics

6.2 Methodological steps for the measurement of Critical Mass in the case of ERA-NETs

Based on this Analytical Framework, the methodological steps for assessing Critical Mass in the case of ERA-NETs are summarized in figure 6.2 and presented in the sections that follow.

Figure 6.2 Assessment of the Critical Mass in the ERA-NET case



The first step is to identify Critical Mass objectives (**A1**) which can be done using a combination of assessment methods (see paragraph 6.3) and partly on the basis of the hypothesis (**H1**) about the impact of the profiles of contextual factors on the selection of specific Critical Mass Objectives.

On the other hand, assuming from above that the Critical Mass objective is known, an assessment must be carried out as to whether Critical Mass has been achieved. A direct assessment as to whether Critical Mass has been achieved, i.e. the threshold level of resources that is required to reach a given "Critical Mass objective", would assume that the following two conditions have been met:

- The ability to directly measure the resources and their absorptive and learning capacity
- Knowing the relationship between the level of resources and the degree to which the objective has been achieved, perhaps in the form of some kind of production function

To meet the first condition, the resources and their characteristics (information about the projects and the beneficiaries) need to be observable. It might be possible to gather this type of information for some FP instruments, but be barely observable in other programmes, especially in the case of ERA-NETs - as will be shown in the empirical analysis. The second condition is clearly beyond reach.

For these reasons, the study took another methodological route: it first tried to assess (**A2**), whether the Critical Mass objective had been reached, the basic hypothesis being that if the Critical Mass objective had been reached, it implies *by definition* that Critical Mass has also been achieved. The next step in the analysis would be to assess the coherence and compatibility between objectives and achievement (**A3**), and the last step was to test the hypothesis regarding the influence that contextual factors (**H2**) and determinants (**H3**) have on achieving Critical Mass and to link it with some characteristics of the resources utilised.

6.3 Assessing Critical Mass objectives: self-assessment and contextual factors

As regards the A1 assessment of figure 6.2, figures 6.3 through to 6.6 show the self-assessment of Critical Mass objectives for the ERA-NETs responding to the survey, grouped by sector. For each ERA-NET, bars show the percentage people answering the questionnaire whose ERA-NET addressed that particular objective. Multiple choices were possible. These figures give a preliminary overview on the coherence of certain Critical Mass objectives with sectors. For example, a "scientific challenge" is considered an objective by the majority of respondents of many ERA-NETs in the Life Science sector, while in other sectors this objective is almost absent (especially in industrial-oriented ERA-NETs of Industrial Technologies and SMEs) or randomly present (as in Transport and Environment sectors). In the case of the "defensive reasons" objective however, quite the opposite is true.

In the second point, contextual factors were used - in the self-assessment - to determine the coherence of a Critical Mass objective to the conditions of the technological field pertinent to the ERA-NET in question. A Critical Mass objective would be considered inappropriate if it was not compatible with certain contextual factors (i.e. specific scientific/techno and geographical conditions, innovation systems, policy, and markets) that might influence the type of objectives assigned to reach Critical Mass.

Figure 6.3 Assessment of Critical Mass objectives: Transport sector

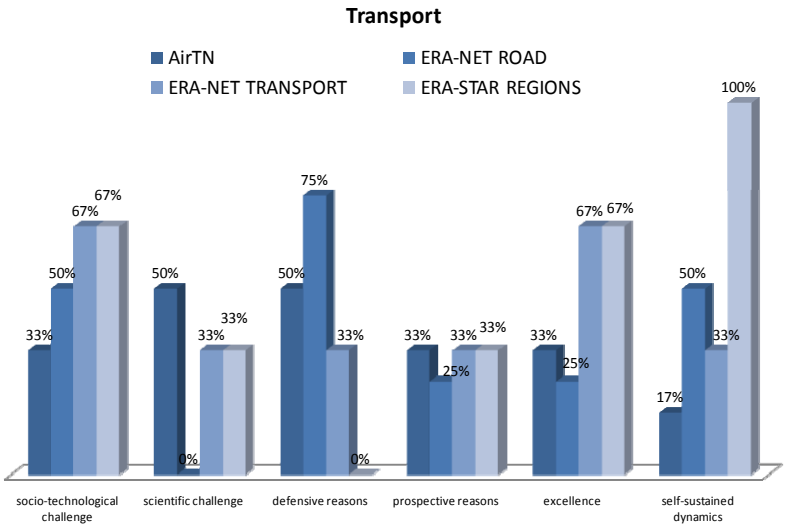
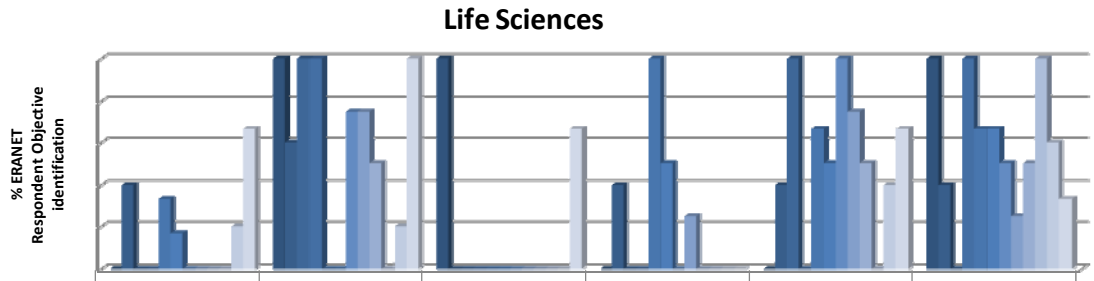
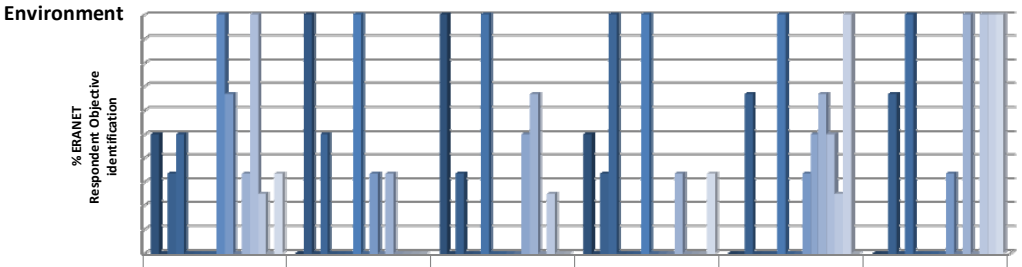


Figure 6.4 Assessment of Critical Mass objectives: Life Sciences sector



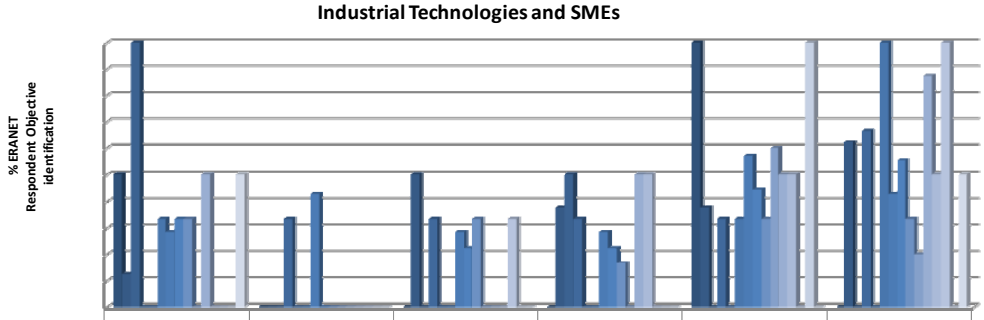
	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
ERA-AGE	0%	100%	100%	0%	0%	100%
ERA-IB	40%	60%	0%	40%	40%	40%
ERA-PG	0%	100%	0%	0%	100%	0%
E-Rare	0%	100%	0%	0%	0%	100%
ERASysBio	33%	0%	0%	100%	67%	67%
EUROTRANS-BIO	17%	0%	0%	50%	50%	67%
NEURON	0%	75%	0%	0%	100%	50%
PathoGenoMics	0%	75%	0%	25%	75%	25%
PRIOMEDCHILD	0%	50%	0%	0%	50%	50%
PV-ERA-NET	0%	0%	0%	0%	0%	100%
SAFEFOODERA	20%	20%	0%	0%	40%	60%
SEE-ERA-NET	67%	100%	67%	0%	67%	33%

Figure 6.5 Assessment of Critical Mass objectives: Environment sector



	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
AMPERA	50%	0%	100%	50%	0%	0%
BIODIVERSA	0%	100%	0%	0%	0%	0%
BONUS	33%	0%	33%	33%	67%	67%
CIRCLE	50%	50%	0%	100%	0%	0%
COMPERA	0%	0%	0%	0%	0%	100%
Crue	0%	0%	100%	0%	0%	0%
ECORD	0%	0%	0%	0%	100%	0%
EUROPOLAR	0%	100%	0%	100%	0%	0%
IWRM.Net-CA	100%	0%	0%	0%	0%	0%
MariFish	67%	33%	0%	0%	33%	33%
MARINERA	0%	0%	50%	0%	50%	0%
NET-BIOME	33%	33%	67%	33%	67%	100%
SKEP	100%	0%	0%	0%	50%	0%
SNOWMAN	25%	0%	25%	0%	25%	100%
Splash	0%	0%	0%	0%	100%	100%
URBAN-NET	33%	0%	0%	33%	0%	100%

Figure 6.6 Assessment of Critical Mass objectives: Industrial Technologies and SMEs sector



	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
ACENET	50%	0%	0%	0%	100%	0%
CORNET	13%	0%	50%	38%	38%	63%
ERABUILD	100%	0%	0%	50%	0%	0%
EraSME	0%	33%	33%	33%	33%	67%
ERA-SPOT	0%	0%	0%	0%	0%	0%
ETRANET	33%	0%	0%	0%	33%	100%
iMERA	29%	43%	29%	29%	57%	43%
MANUNET	33%	0%	22%	22%	44%	56%
MARTEC	33%	0%	33%	17%	33%	33%
MATERA	0%	0%	0%	0%	60%	20%
MNT ERA-NET	50%	0%	0%	50%	50%	88%
NanoSci-ERA	0%	0%	0%	50%	50%	50%
NEW OSH ERA	0%	0%	33%	0%	0%	100%
SUSPRISE	0%	0%	0%	0%	100%	0%
VISION	50%	0%	0%	0%	0%	50%

In order to empirically measure the contextual factors, two sets of indicators were created:

- Indicators collected from online survey responses
- Indicators collected from official statistics

We suggest that ideally, this two-level measurement should be adopted in any future replications of the analysis. One is the strategy of using the questionnaire to collect information from the players - beneficiaries, projects officers, and programme managers - involved in the R&D programme, whilst the other is to use official statistics as back-up, which also helps dispel any concerns that there might be an element of personal bias, and results in a more objective figure.

In the case of ERA-NETs, the questions in the online survey questions made it possible to gather the following types of information:

- Information about the **contextual factors** in which the R&D programme is carried out. This information relates to:
    - the degree of maturity of the research field
    - the players that dominating the research sector
    - the leading countries
    - the need for research infrastructure
    - the existence of clusters
    - the connection to market
    - the connection to other research fields
    - the player's perceptions or opinions regarding the **type of objectives** that are relevant to the policy or techno/scientific areas in question

On this occasion, official statistics were used as a second source of information, complementing and validating survey responses on **contextual factors**. For instance, patent data made it possible to rank where the EU came on innovation vis-à-vis other world regions (USA and the BRIC countries). Publication statistics made it possible to do the same for scientific excellence issues. Trends for publications and patents provided information about the growth rate of the sector and its level of maturity. Annex 4 shows the results of this analysis of selected cases. The main insight here was that publication and patent data is largely coherent with survey data, which mutually confirms the validity of these two data sources. It seems that survey data is easier to collect than carrying out an analysis of publications and patents to generate data, because the latter requires an intensive study of scientific and technological fields in order to define them properly.

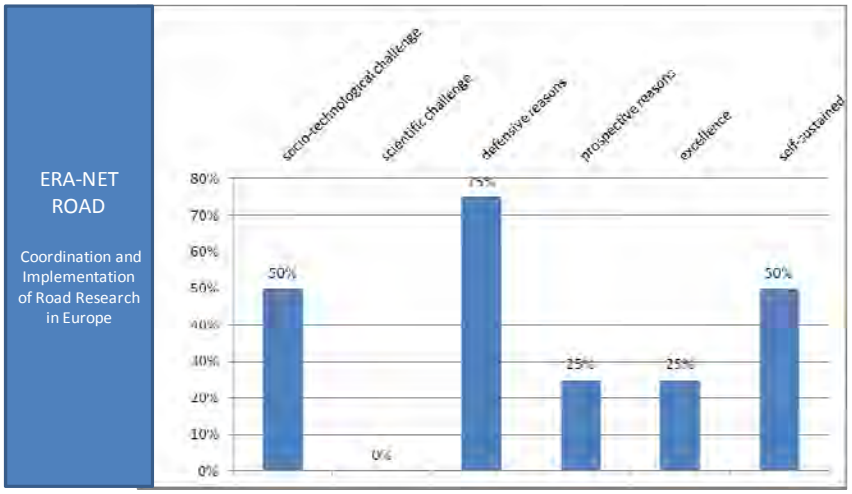
Other types of official statistics (gathered from CIS, Eurostat, OECD, etc.) could be used to build up indicators such as time to market, reflecting the knowledge dynamics of the sector and its ability to claim the innovation or market share.

Empirically, the consistency of objectives was analysed by matching the different factors with the objectives assessed by the players (the self-assessment). It is assumed that the self-assessment of

objectives should match the objectives – or a subset of them – that contextual factors show to be feasible or appropriate. If that match is coherent with the hypothesis, it can be supposed that the hypothesis is supported, and that a specific set of contextual factors implies or can identify specific Critical Mass objectives assigned to the R&D programme. If the match is not coherent, either the theoretical hypothesis is wrong, or the respondents have divergent opinions about the type of objectives relevant to the techno-scientific area in question.

Figures 6.7 to 6.10 below show some examples – for four ERA-NETs, one per sector – of how this application of contextual factors matches the self-assessment – or not. The bars reflect the self-assessment as already presented above, while the sentences in red reflect the answers that ERA-NET Coordinators gave to the specific questions in the online survey regarding: the evolution of their scientific area, the worldwide position of Europe in that scientific area and existing connections to the market and to other research fields. In some cases, stars in the figures below highlight when a specific answer was double checked with external data sources on the issue. Finally, dots report our hypothesis on the coherence of each answer in red with the 6 types of Critical Mass objectives (Hypothesis H1 was outlined in table 4.1).

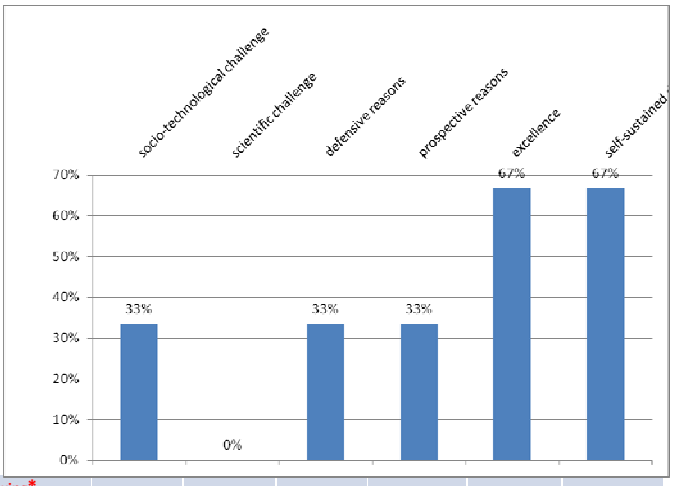
Figure 6.7 Assessment of Critical Mass objectives, based on contextual factors and self-assessment in the Transport sector (ERA-NET ROAD example)



Evolution of S&T area	Mature	●	●	●		●	
Worldwide Position in S&T area	Europe leading	●	●	●	●	●	●
Connection to Market	Future / Foreseeable Market	●	●		●	●	●
Connection to other research fields	Heavily connected as user and/or supplier	●	●		●	●	●

Figure 6.8 Assessment of Critical Mass objectives, based on contextual factors and self-assessment in the Environment sector (BONUS ERA-NET example)

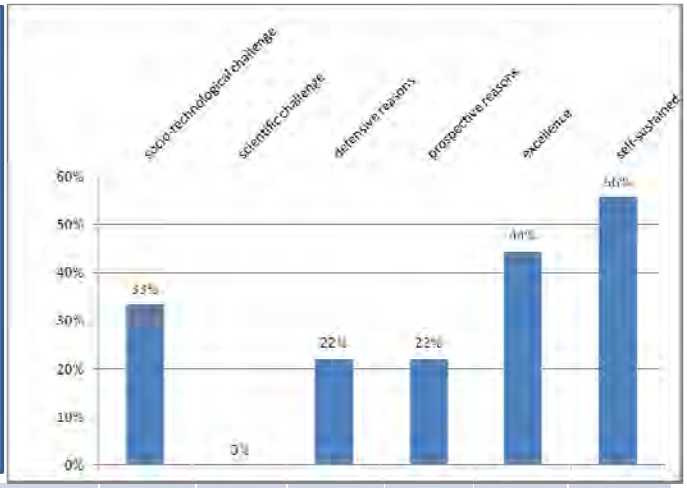
BONUS for the Baltic Sea Science - Network of Funding Agencies



Evolution of S&T area	Growing*	●	●		●	●	●
Worldwide Position in S&T area	Europe is not leading	●	●	●	●	●	●
Connection to Market	Future/Foreseeable Market	●	●		●	●	●
Connection to other research fields	Relatively independent from the developments in other research areas		●	●	●	●	

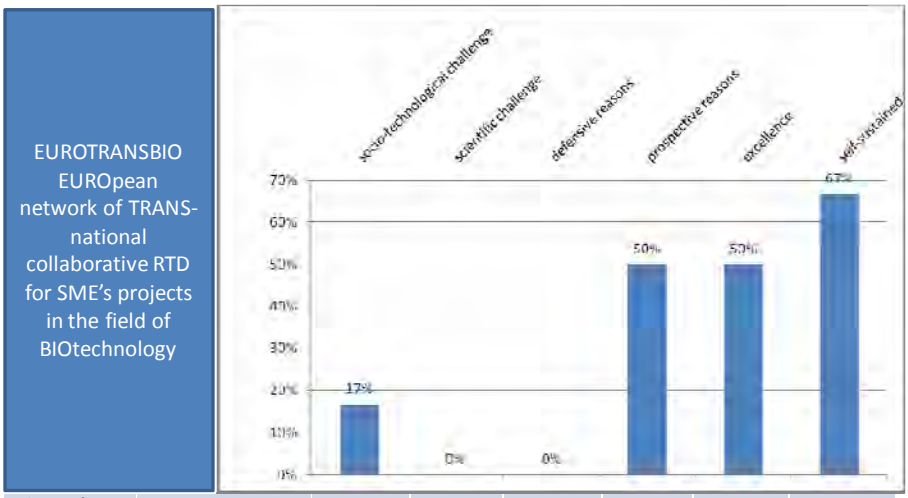
Figure 6.9 Assessment of Critical Mass objectives, based on contextual factors and self-assessment in the Industrial Technologies and SMEs sector (MANUNET ERA-NET example)

MANUNET Walking towards an European regionally based research area on new processes and flexible intelligent manufacturing systems



Evolution of S&T area	Growing	●	●		●	●	●
Worldwide Position in S&T area	Europe leading	●	●	●	●	●	●
Connection to Market	Directly to Existing Mature Market	●		●		●	
Connection to other research fields	relatively independent from the developments in other research areas		●	●	●	●	

Figure 6.10 Assessment of Critical Mass objectives, based on contextual factors and self-assessment in the Life Sciences sector (EUROTRANSBIO ERA-NET example)



Evolution of S&T area	Growing*	●	●		●	●	●
Worldwide Position in S&T area	Europe not leading*	●	●	●	●	●	●
Connection to Market	Directly to Existing launched and growing Market	●				●	
	where Europe in not leading	●		●		●	
Connection to other research fields	relatively independent from the developments in other research areas		●	●	●	●	

The figures can be read in the following way: in order to assess the Critical Mass objective whether it is achieved, contextual factors and self-assessment must both be considered. In some cases, there is a high coherence of the two. For example, the "socio-technological challenge" is considered an objective for 50% of ERA-NET ROAD respondents. This tallies with all contextual factors identified: the scientific area is mature, Europe is a world leader in this field, there is a connection with future/foreseeable markets and the area is heavily connected to other research fields. Similarly, the "excellence" objective for BONUS is considered an objective by 67% of survey respondents and this fist with several contextual factors that have been identified: the scientific area is growing, there is a connection with future /foreseeable markets and the area is relatively independent of other research fields. All such factors are considered coherent with addressing an "excellence" objective for Critical Mass.

Overall, the coherence of contextual factors and self-assessment in the data set is very good. In 19 cases where full information was available, i.e. the availability of a complete set of data on both contextual factors and self-assessments by ERA-NET coordinators and respondents, only 8.8% were a mismatch. This means that with only 10 of a potential 114 cases (19*6= 114) in disagreement, the majority of respondents (>50%) considered that a policy objective was applicable to their respective ERA-NETs, but when contextual factors were applied, this policy objective appeared to be inappropriate to the ERA-NET in question.

While this number of mismatches might be acceptable, we find that almost all of them occur in assessing two policy objectives: securing a certain level of competencies for defensive reasons and

establishing self-sustained dynamics. Information from the qualitative interviews tells us that respondents had different things in mind regarding these objectives. Moreover, in some cases the interviews yielded very clear insights into certain ERA-NET objectives. In the case of ERA-NET ROAD for example, it clearly showed that "securing competencies for defensive reasons" is a relevant objective, however the indicators for contextual factors were not necessarily coherent, which would seem to indicate that this policy objective is not applicable to this research field.
The deterministic application of this coherence check to identify the Critical Mass objectives in each case should therefore be avoided. In order to give credit to the fact that each measure produces some "incoherencies", probabilistic" and qualitative elements were taken into consideration in the final step:

- Another criterion for self-assessment was added in order to allow for cases, where the self-assessment of respondents appeared to be highly incoherent. In addition to the criteria that most respondents regarded as a relevant objective for an ERA-NET, an objective was also held to be of relevance to an ERA-NET if the coordinator indicated this was so..
- It is held that when available, strong qualitative information from the interviews can be used to allow for any mismatches due to incoherencies in the indicators for contextual factors.

This procedure finally led to a set of policy objectives for each ERA-NET. It was assumed that the ERA-NETs intended to establish Critical Masses of resources in order to reach these policy objectives. In addition to the intended effects, others might show up – unintentionally, one might say – namely effects on to policy objectives not envisaged in the beginning. Reference will be made to this point again in section 6.5. Table 6.2 shows the policy objectives of the ERA-NETs.

Table 6.2 Identified objectives of ERA-NETs for which a pooling of a Critical Mass of resources is relevant

ERA-NET	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
ACENET					X	
AirTN	**X**		**X**			
AMPERA	**X**					
BIODIVERSA		X				
BONUS	X			**X**	**X**	X
CIRCLE	**X**	**X**		**X**		
COMPERA						X
CORNET	**X**					
Crue			X			
ECORD					X	
ERA-AGE		X	X			X
ERABUILD	X					
ERA-IB	**X**				**X**	
ERA-NET ROAD	**X**		**X**		**X**	
ERA-NET TRANSPORT	X				X	
ERA-PG		X			X	
E-Rare		X				X
EraSME			X		X	
ERA-SPOT	X				X	
ERA-STAR REGIONS	X				X	X
ERASysBio				**X**	**X**	**X**
ETRANET						X
EUROPOLAR		X		X		
EUROTRANS-BIO					**X**	
iMERA	X					
IWRM.Net-CA	X					
MANUNET					**X**	
MariFish	**X**					
MARINERA			X		X	
MARTEC			X		X	
MATERA					**X**	
MNT ERA-NET	**X**				**X**	
NanoSci-ERA				X	X	X
NET-BIOME	**X**	**X**		**X**	**X**	**X**
NEURON		**X**			**X**	**X**
NEW OSH ERA						X
PathoGenoMics		**X**			**X**	
PRIOMEDCHILD		X			X	X
PV-ERA-NET						X
SAFEFOODERA	X					
SEE-ERA-NET	**X**	**X**			**X**	**X**
SKEP	X					
SNOWMAN					**X**	**X**
Splash					X	X
SUSPRISE					X	
URBAN-NET						**X**
VISION	X					X
SUM	**20**	**11**	**7**	**6**	**26**	**18**
n=47	**43%**	**23%**	**15%**	**13%**	**55%**	**38%**

Note: Identification based on contextual factors of the S&T areas (incl. qualitative information about context) and / or self-assessment of respondents; those cases, for which full information is available are highlighted in blue.

The final result showed that the method suggested to approximate Critical Mass objectives led to the identification of an average of two objectives per ERA-NET (1.8 precisely). The objective to reaching excellence prevailed, followed by the addressing of socio-technological challenges and reaching self-sustained dynamics. Addressing specific scientific challenges applied to a quarter of the cases, whilst the objective to secure competencies for defensive or prospective reasons rarely

appears. These numbers appear to be quite plausible, as reaching excellence, for example, is a very basic rationale behind an ERA. Other numbers show that ERA-NETs comprise a larger share of application-oriented fields than basic research fields (see the numbers regarding socio-technological vs. scientific challenges. The fact that the objective to "secure a level of competencies" was seldom chosen, can be connected to the fact that the hypothesis linking contextual factors to objectives leads to a somewhat restrictive selection here, and this creates some incoherencies. These were allowed for in some cases, by applying a qualitative check using information from the case study interviews.

6.4 Assessing Critical Mass Achievement

This section presents how, for those ERA-NETs analysed, achieving Critical Mass was measured.

6.4.1 Adaptation of the Concept to ERA-NETs

As proposed in the definition, reaching Critical Mass corresponds to achieving the objective underlying the search for Critical Mass. In other words, measuring to what extent Critical Mass is achieved, depends on the type of objective chosen. We defined four broad categories of objectives (which were further divided into six detailed categories), which meant we had four (and six) ways of measuring the degree to which Critical Mass was achieved. This does not mean that the indicators used for this measurement necessarily differed from one case to the other. In essence, many indicators were the same, but they were interpreted from different perspectives so the scope and nature of the indicators varied according to the Critical Mass objective.

The measurement could be made based on two broad types of elements. One type dealt with outputs and the possible outcome and impact that might be triggered by the use and diffusion of those outputs. The other involved further dynamic changes in the research system that were generated by designing and implementing the programme and by carrying out research activities.

- **to address techno-scientific challenges:**

This measurement can be based on the comparison between the challenge itself and what has been achieved. The measurement will then depend on the nature of this objective. In the event that the objective has a technological bent, or if it encompasses a social element, the measurement is more likely to be based on more application, commercial, or social welfare oriented outputs. If the objective is more scientific, the measurement will be based on academic outputs. The more the challenge is precisely defined (in terms of characteristics, properties, functionalities, etc) the more the measurement is non-subjective.

- **to secure a certain level of competencies for defensive or prospective reasons**

In essence, in terms of measurement, the same approach used in the second type of objective is also valid here. The main (but crucial) difference is that the "level of competencies" to be measured is practically impossible to express in direct, measurable terms. It means achievement can only be measured by using a set of proxy measures (e.g. publications showing the capacity to

master a certain field of knowledge, or the amount of resources that directly measure the components of Critical Mass research activities), or by perceptual measures derived from selected stakeholders.

- **to reach excellence**

In this case, the measurement may be more directly observable as it is expressed in terms of ranking (in absolute or comparative terms), and that ranking is itself based on objective measures. In that scenario, mostly academic outputs are used, possibly complemented by commercial and/or social welfare outputs when they can be clearly related to an evaluation of the excellence of European R&D in a given area.

- **to reach self-sustained dynamics**

This objective requires the measurement of sizeable evolution of the S&T system. This measurement could be made at least at four levels:

- the level of the resources themselves - by looking at the quantity and quality of resources (including for instance the type of players) that are mobilized, in comparison with the "potential" resources that actually could be mobilized in a given field
- the level of activities/projects - by looking at the response rate to calls, the pervasiveness of the topics targeted by programmes underway across countries/regions and by the convergence of the definitions of those topics and of the perception of their importance
- the level of the outputs - in terms of rate of increase in the outputs produced
- the level of the relationship between R&D the players in terms of connectivity, centrality and other measurements used, for instance, in social network analysis

6.4.2 Empirical Application

This section will describe steps A2 and A3 of the assessment in which empirical checks are carried out to see:

- whether the pooling of resources generated by ERA-NET activities and coordination leads to outputs, outcomes or impacts relevant to the achievement of policy objectives related to Critical Mass (A2),
- whether, once the A1 assessment (described above) has been completed, actual achievement is coherent with the objectives determined to be compatible and relevant for each ERA-NET

In practice, different methods were adopted and will be described in the paragraphs that follow:

a) "direct self-assessment" by the players involved in the programmes (in the specific case of ERA-NETS, this meant the participants in particular), who were asked directly about their own

view on the level of achievement of the various Critical Mass objectives possible (through the online questionnaire and vis-à-vis interviews)[20].

b) an "indirect self-assessment" by the players involved in the programmes (particularly the participants, in the specific case of ERA- NETs), who were asked about the output / outcome / impact of the programmes (through the online questionnaire and vis-à-vis interviews)[21].

c) an "independent/external" assessment resulting from an analysis of the information gathered from other standardized sources, such as bibliometrics and patent statistics, on output / outcome / impact and on other more dynamic changes in the S&T field such as increasing activity, the increasing involvement of industry or local authorities, etc. [22]

These three approaches to assessment were supported by effecting a "combined assessment", i.e. an assessment that uses all the different qualitative information gathered through the interviews with the players involved in the programmes, as well as from a mix of other sources such as website, reports, studies, etc.

Approach b) is key. Table 6.3 in particular summarizes the hypothesis on how specific indicators or patterns of indicators are linked to specific types of Critical Mass objectives; it shows that the six types of Critical Mass objectives leading to six different methods of measuring achievement.

Then, achievement was measured as a ratio, that expressed, for each type, the quotient of output indicators observed against the total expected. Figures 6.11 to 6.14 present the achievement ratios for all ERA-NETs divided by sector.[23]

[20] This indicator has been tested, but not used in the final assessment. Given the inconsistencies found with the indirect self-assessment data, we agreed to rely on these (semi-)objective indicators only.

[21] Question: "which of the following types of results do you expect or already witness?" Including the "expected outputs" in this question resulted from the pilot interviews where it had become obvious, that after such short term time-spans between the start of the ERA-NET funding for many of the research projects and the timing of our study will hardly show manifestation of outputs, outcomes or impacts already.

[22] These indicators have been explored on an illustrative, case-wise level, see Annex 4.

[23] As a cross-check we have also calculated a weighted ratio measure, which gave double weight to the most important indicators, but this lead only to minor differences, therefore the simpler measure is being presented here.

Table 6.3 Indicator breakdown to Critical Mass Objectives

	Socio-technological challenge	Scientific challenge	Securing competence / defensive	Securing competence / prospective	Excellence	Self-sustained dynamics
Academic returns of the RTD projects						
patents at the European and US patent offices (invention/claims, applications/granted, ownership regimes…) + patent citations	X		X	X	X	X
other IPR (Copyrights, trademarks, etc.)	X					
scientific publications and most cited publications / bibliometrics (such as breadth of technological impact)		X	X	X	X	X
scientific prizes		X			X	
additional researcher (including post-doc, PhD etc) employed through R&D programmes						X
Private exploitable returns of the RTD projects						
licensing	X		X	X		
spin-offs companies generated				X		X
new processes, products and services	X					
standard, norms	X					X
improved processes, products and services			X			
step forward a new stage of development (basic research, prototype, software code…)		X		X		
new research contracts				X	X	X
new training programmes				X		X
networking			X	X		X
increase / rate of innovative firms cooperating with other firms/universities/public research institutes						X
increasing number of actors (universities labs, PRO, firms etc) active in the field				X		X
Social returns (spillover) of the RTD projects						
creation, access to new research fields		X		X		X
creation, access to new markets	X			X		X
enhanced cooperation with third countries					X	
position in international ranking		X			X	
market share of the EU / world business sector					X	
enhanced science-industry linkages	X					X
changes in employment levels	X					X

Note: Indicators highlighted in red are assumed to be most important.

Figure 6.11 Achievement of Critical Mass objectives: Transport sector

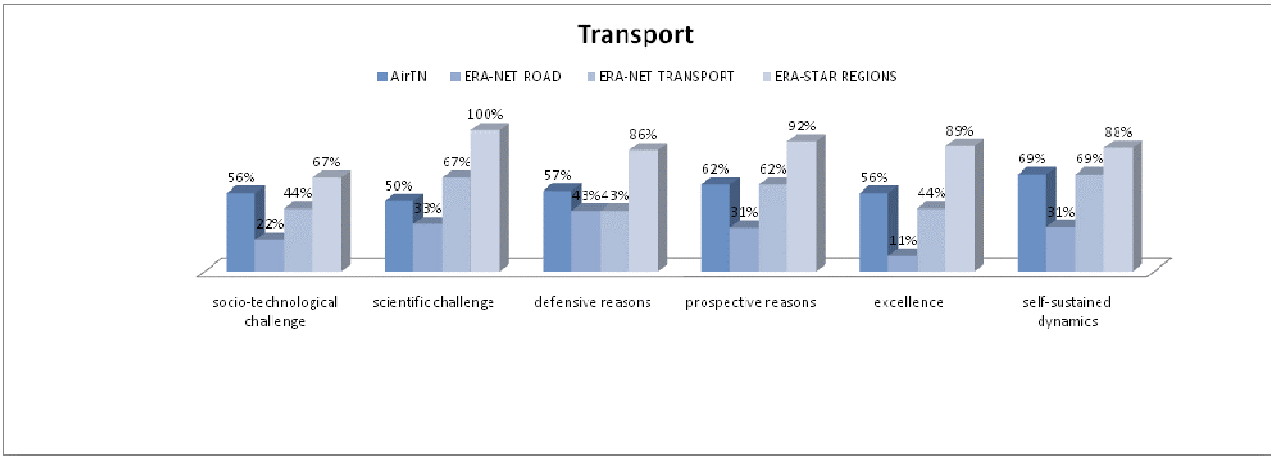
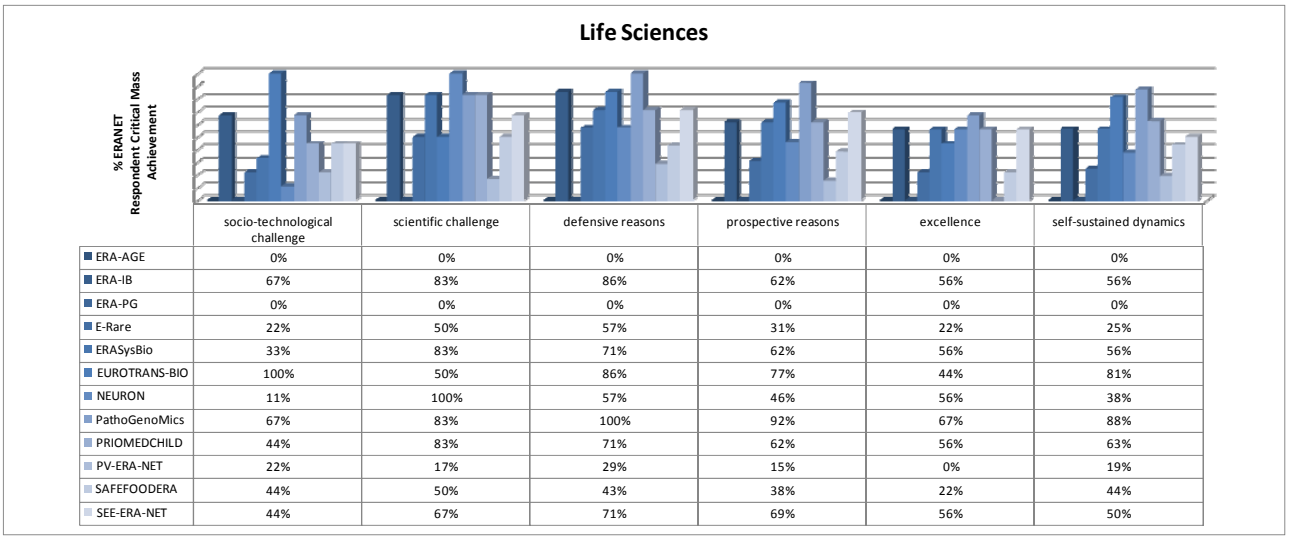
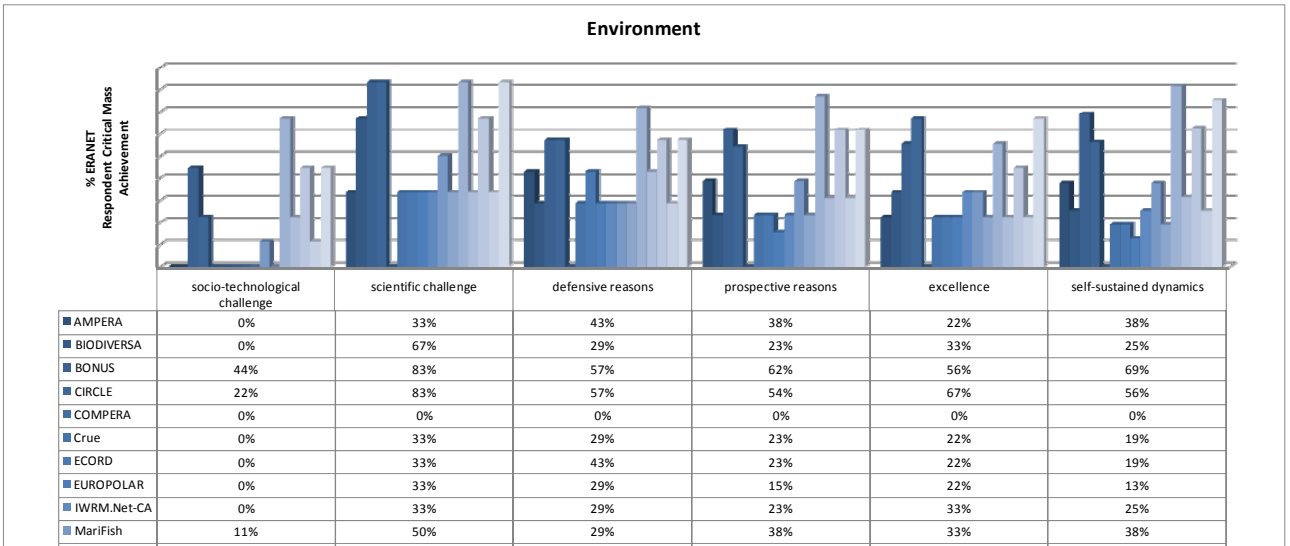


Figure 6.12 Achievement of Critical Mass objectives: Life Sciences sector



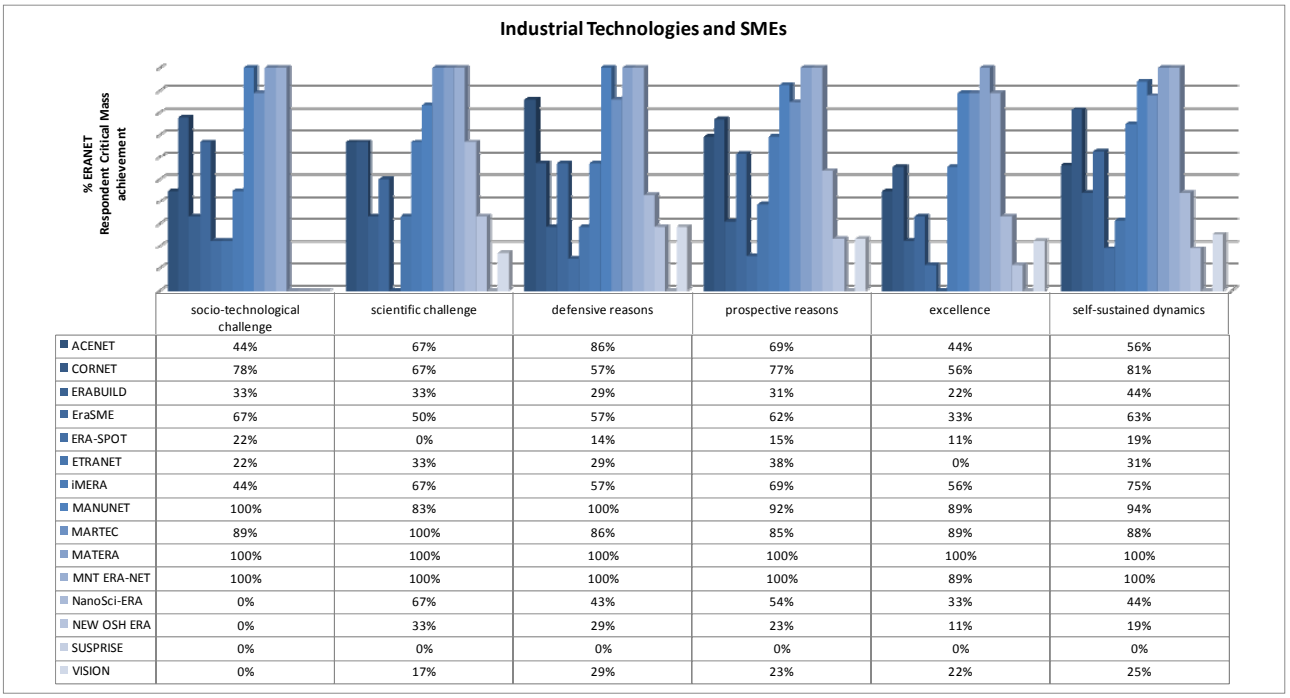
	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
ERA-AGE	0%	0%	0%	0%	0%	0%
ERA-IB	67%	83%	86%	62%	56%	56%
ERA-PG	0%	0%	0%	0%	0%	0%
E-Rare	22%	50%	57%	31%	22%	25%
ERASysBio	33%	83%	71%	62%	56%	56%
EUROTRANS-BIO	100%	50%	86%	77%	44%	81%
NEURON	11%	100%	57%	46%	56%	38%
PathoGenoMics	67%	83%	100%	92%	67%	88%
PRIOMEDCHILD	44%	83%	71%	62%	56%	63%
PV-ERA-NET	22%	17%	29%	15%	0%	19%
SAFEFOODERA	44%	50%	43%	38%	22%	44%
SEE-ERA-NET	44%	67%	71%	69%	56%	50%

Figure 6.13 Achievement of Critical Mass objectives: Environment sector



	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
AMPERA	0%	33%	43%	38%	22%	38%
BIODIVERSA	0%	67%	29%	23%	33%	25%
BONUS	44%	83%	57%	62%	56%	69%
CIRCLE	22%	83%	57%	54%	67%	56%
COMPERA	0%	0%	0%	0%	0%	0%
Crue	0%	33%	29%	23%	22%	19%
ECORD	0%	33%	43%	23%	22%	19%
EUROPOLAR	0%	33%	29%	15%	22%	13%
IWRM.Net-CA	0%	33%	29%	23%	33%	25%
MariFish	11%	50%	29%	38%	33%	38%
MARINERA	0%	33%	29%	23%	22%	19%
NET-BIOME	67%	83%	71%	77%	56%	81%
SKEP	22%	33%	43%	31%	22%	31%
SNOWMAN	44%	67%	57%	62%	44%	63%
Splash	11%	33%	29%	31%	22%	25%
URBAN-NET	44%	83%	57%	62%	67%	75%

Figure 6.14 Achievement of Critical Mass objectives: Industrial Technologies and SMEs sector



	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
ACENET	44%	67%	86%	69%	44%	56%
CORNET	78%	67%	57%	77%	56%	81%
ERABUILD	33%	33%	29%	31%	22%	44%
EraSME	67%	50%	57%	62%	33%	63%
ERA-SPOT	22%	0%	14%	15%	11%	19%
ETRANET	22%	33%	29%	38%	0%	31%
iMERA	44%	67%	57%	69%	56%	75%
MANUNET	100%	83%	100%	92%	89%	94%
MARTEC	89%	100%	86%	85%	89%	88%
MATERA	100%	100%	100%	100%	100%	100%
MNT ERA-NET	100%	100%	100%	100%	89%	100%
NanoSci-ERA	0%	67%	43%	54%	33%	44%
NEW OSH ERA	0%	33%	29%	23%	11%	19%
SUSPRISE	0%	0%	0%	0%	0%	0%
VISION	0%	17%	29%	23%	22%	25%

In terms of sectors, the distribution of achieved objectives appears to be quite homogenous. In other words, no particular association between a sector and a specific objective emerged with the exception of the low level of Socio-technological objective in the Environment sector.

Based on our measurement, it also appears that not all of the objectives identified as relevant policy objectives for the ERA-NETs were reached. We also noted that objectives unidentified in the first place had also been achieved. Table 6.4 therefore, focuses on the achievement of Critical Mass objectives only if they were compatible with table 6.2. In other words, what was measured was the Critical Mass achievement of objectives clearly set from the outset.

Table 6.4 Achievement of intended Critical Mass objectives

ERA-NET Sector	ERA-NET Name	socio-technological challenge	scientific challenge	defensive reasons	prospective reasons	excellence	self-sustained dynamics
Environment	AMPERA	0%					
	BIODIVERSA		67%				
	BONUS				62%	56%	
	CIRCLE	22%	83%		54%		
	COMPERA						0%
	Crue			29%			
	ECORD					22%	
	EUROPOLAR		33%		15%		
	IWRM.Net-CA	0%					
	MariFish	11%					
	MARINERA			29%		22%	
	NET-BIOME	67%	83%		77%	56%	81%
	SKEP	22%					
	SNOWMAN					44%	63%
	Splash					22%	25%
	URBAN-NET						75%
Industrial Technologies and SMEs	ACENET					44%	
	CORNET	78%					
	ERABUILD	33%					
	EraSME			57%		33%	
	ERA-SPOT	22%				11%	
	ETRANET						31%
	iMERA	44%					
	MANUNET					89%	
	MARTEC			86%		89%	
	MATERA					100%	
	MNT ERA-NET	100%				89%	
	NanoSci-ERA				54%	33%	44%
	NEW OSH ERA						19%
	SUSPRISE					0%	
	VISION	0%					25%
Life Sciences	ERA-AGE		0%	0%			0%
	ERA-IB	67%				56%	
	ERA-PG		0%			0%	
	E-Rare		50%				25%
	ERASysBio				62%	56%	56%
	EUROTRANS-BIO					44%	
	NEURON		100%			56%	38%
	PathoGenoMics		83%			67%	
	PRIOMEDCHILD		83%			56%	63%
	PV-ERA-NET						19%
	SAFEFOODERA	44%					
	SEE-ERA-NET	44%	67%			56%	50%
Transport	AirTN	56%		57%			
	ERA-NET ROAD	22%		43%		11%	
	ERA-NET TRANSPORT	44%				44%	
	ERA-STAR REGIONS	67%				89%	88%

Overall, there were fairly high levels of achievement levels in this indirect self-assessment. By linking the output indicators to objectives, it was found that on average, objectives were reached as indicated below:

- socio-technological challenges - 39%.
- scientific challenges - 59%.
- securing competencies for defensive reasons - 43%.
- securing competencies for prospective reasons - 54%.

- reaching excellence - 48%.
- reaching self-sustained dynamics - 41%.

The insights gleaned from these figures are as follows:

- In testing if the objectives set had been achieved, this was seen to be so, albeit at different levels. This result was not a surprise as it has been anticipated by the high levels of achievement seen in the indicator-based self-assessment.
- The good results in terms of achievement were not unexpected. The ERA-NET scheme is well known to be a successful measure and to show good results, and this study simply reconfirms this. It seems that many of the ERA-NETs are also able to perform well in terms of pooling Critical Mass in order to address certain policy objectives. In this respect, it also makes sense that for some ERA-NETs in particular, addressing socio-technological challenges had not been achieved, as it is only to be expected that this type of objective takes time to achieve.

6.5 Explaining Critical Mass Achievement

A set of determinants relevant to achievement was identified within the parameters of the Analytical Framework. The determinants are those elements that offer different characteristics, levels and combinations of resources. It is assumed that a ***Critical Mass of resources*** is necessary to reach certain policy objectives. It is further assumed that this Critical Mass encompasses the ***characteristics*** of the resources (in terms of amount, quality, diversity, etc), and also their ***combination*** (how complementary they are etc.), and the ***absorptive and learning capacities*** of the players that provide/constitute these resources. In essence, "resources" is used here to include a range of resources that include human and physical (instrumentation, infrastructure etc), and financial, as well as knowledge and information. For the purpose how they ***apply to ERA-NETs*** they will gauged by the aspects listed belows:

- ERA-NET participants (national and regional institutions that own and/or manage R&D programmes that are deemed to be determinants of an intermediate level)
- ERA-NET activities, mainly calls in collaborative R&D projects, but also their non-R&D activities (networking, benchmarking, strategy building, etc.)
- Collaborative R&D projects funded by ERA-NET calls
- R&D players conducting these projects (beneficiaries)

Table 6.1 looks again at the H3 hypothesis as applied to ERA-NETs regarding the link between determinants, resources and achieving Critical Mass. The step that follows explains in detail how that hypothesis was tested. (see table 6.5 below).

Table 6.5 Data availability and Operationalisation of Determinant Variables

Determinants	Variable Names	Description
Participants		
number	numpart	Number of Partners in ERA-NET (FP6)
diversity	divers1	Number of Countries in ERA-NET (FP6)
	dvers2	Presence of different country groups: range from 1 to 4; count, when present: EU15big, EU15 small/rest, EU12new, outsideEU
	divers3	Dummy var., if any relevant country is missing in ERA-NET (expected to be negatively related to achievement)
	divers4	Dummy var., if one of the EU big 5 countries is missing (expected to be negatively related to achievement)
	divers5	Diversity of individual rationales of partners, see table 5.4 (with 1=full coherence) (expected to be positively related to achievement, i.e. the more coherent the rationales, the better the achievement)
previous links/cooperation between participants		data n.a.
Activities		
coherence with national/regional programmes		data n.a.
calls: number	numcall	Number of calls of ERA-NET
calls: amount of money	callbudg	Total of public budget allocated in (all) the calls of the ERA-NET in €
	avbudget	Average Public Budget per participating partner per call
calls: quality of selection of the beneficiaries		data n.a.
calls: participants involvement	partnerp	Average Number of partners per call
	partinvo	partnerpercall as a share of numpart
calls: industry involvement		data n.a.
existence of complementary R&D actions	rdcompl	Dummy, if activities related infrastructure development, joint training or exchange of researchers have been performed
coordination activities/ non R&D activities	activdiv	number of different non-R&D activities, see note in section 5.2
	coordfun	EC funding per participant
	coordman	Average effectiveness rating for joint activities
quality of ERA-NET management	coordma0	Average rating for coherence of objectives of joint activities
	coordma1	Average rating for coherence of implementation of joint activities
	motiv_c	Sum of individual motives of coordinator implying commitment to joint activities (max.3), see table 5.4
Projects		
number of projects	numproje	Number of projects funded by the ERA-NET
amount of money for projects	projectb	Average budget for projects funded by the ERA-NET
duration of project	projectd	Average duration of projects
novelty of anticipated results	novelres	Share of respondents who expect radically new results from some projects funded by the ERA-NET
orientation towards development	orientat	Share of respondents who classify the projects funded by the ERA-NET as being development oriented (expected to be positively linked to achievement wrt socio-techn. Challenges)
diversity of projects		data n.a.
Beneficiaries		
number of beneficiaries	benefici	Average number of beneficiaries/partners per project
quality of beneficiaries		data n.a.
diversity of beneficiaries		data n.a.
previous links/cooperation between beneficiaries		data n.a.

Data sources: Critical Mass survey S1-C and S1-P (shaded in dark blue), CORDIS/ European Commission (light blue), for variables marked in both colours, CORDIS has been used, but was updated by Critical Mass data; desk research (white/not coloured).

The ERA-NET scheme operates at the level of programme owners and managers, who are obviously the most relevant source of data for any empirical investigation. It means that a significant quantity of data is available about the participants and their activities, but there is **no coherent information available about ERA-NET projects and beneficiaries.** (see section 5.5.2). For example, we know the number of projects and the average number of partners (beneficiaries) per project, but know nothing about the diversity of projects or beneficiaries or any previous links

between the beneficiaries or their quality.[24] These variables are part of the hypotheses that deal with achieving following objectives: Addressing socio-technological and scientific challenges, and self-sustained dynamics. Whether these variables are of minor **importance** or are relevant, omitted variables **can be identified when analysing the explanatory power** of the three models analysing the achievement of the objectives.

Other missing variables can almost certainly be **ignored, as it can be assumed that they are strongly correlated to variables that could be included in the analysis**. This is true when considering the quality of the selection process for ERA-NET projects as it can be assumed that it is positively correlated to good ERA-NET coordination management. Another example is the previous relationship between ERA-NET participants or the coherence of ERA-NET activities with national programmes, both of which should also be reflected in the high coherence of the motivations of participants to join the ERA-NET.

Finally, qualitative empirical analysis showed that the involvement by industry in the financing of ERA-NET calls is overall very low, as ERA-NETs mainly focus on pooling public funds, so this variable would most likely have **too low a variation** to have any impact on the results of the analysis and can therefore also be **ignored**. [25]

Annex 4 provides descriptive statistics for the independent variables (number of observations, maximum, minimum and mean values) shown in table 6.5.

Each of the six policy objectives were analysed in the following ways:

- Bivariate correlations with all indicators for determinants/resources
- OLS regressions with those indicators assumed to be influential in achieving the objective according to the hypotheses

In order to learn more about the relationships between the determinants, a study was made of the bivariate correlations that existed beforehand. (see the Annex for the results).

Several interesting patterns, i.e. correlations at a statistically significant level (Pearson), were apparent:

- The number of ERA-NET participants is linked to indicators regarding the diversity of participants (number of countries represented in the ERA-NET, diversity of countries, i.e. EU-15 big, EU-15-small, EU-12-new, other). Moreover, it is negatively linked to the coordination funding available - i.e. the more partners the less coordination funding is available per capita

[24] We have explored the possibility of using publication and patent data to close this gap, e.g. for collecting data about the excellence of beneficiaries (via citations for example), but this has been done only for a very few cases as it requires intensive work (see the Annex for more details).

[25] In addition to determinants, contextual factors might affect why the determinants are different from one area to the other, or why the same determinants have different impact on the achievement of the Critical Mass. As they are often very contextual and case-specific, there were no data available allowing for an operationalization of them for the whole data set. We have however in line with the analytical framework taken into account how contextual factors explain why a specific policy objective is assigned to a S&T area, and as has been shown in section (xx on identifying relevant policy objectives), the most relevant contextual factors have been considered here. Therefore, these variables cannot be used in the quantitative analysis for a second time, in order to avoid tautological reasoning.

- The number of countries represented in the ERA-NET is positively connected to the average budget of funded projects and the average number of project beneficiaries
- Where one or more relevant partners in an ERA-NET are missing, the coherence of individual motivations of those partners in the ERA-NET is smaller. One can only guess about causal meanings here. Either relevant partners are missing because of the rather high diversity of motives of the partners in an ERA-NET or the partners already in the ERA-NET have different expectations or because it is less clear as to whether it will be successful or that other relevant partners are missing
- The amount of funding pooled for ERA-NET calls is correlated to the number of calls and to the number of partners contributing to the calls and partly to both the number of funded projects and the amount of funding available for coordinating the ERA-NET. The specifics of this last finding is that higher coordination funding (measured per capita) is generally correlated to calls with higher budgets
- The variables related to the different aspects of ERA-NET coordination (overall effectiveness and coherence of activities) are correlated but not to the individual motivation of the ERA-NET coordinator. The coordination variables are in fact correlated partly to the budget of calls, the existence of complementary R&D activities and to several project-related aspects such as the number of projects, their duration and budget as well as the expectation that these projects will bring about radical new results. The diversity of countries is another factor - i.e. EU-15 big, EU-15-small, EU-12-new, other
- Research projects with a development orientation have smaller project budgets and shorter project duration
- Projects of longer duration are also more often linked to the expectation that these projects will bring about radical new results

These observed patterns of correlations are generally as one would expect and should be borne in mind when running regression analyses. They should also be given priority within a set of inter-correlated variables, for inclusion in the models for which a theoretical hypothesis has been formulated.

The choice to running regression analyses on achievement ratio variables was one taken with caution, as there were only 49 cases in the sample. This meant that patterns observed in such a small dataset might be blurred by even very slight deviations. On the other hand, 49 cases were too many to be substantially analysed for patterns by case-wise analysis only. Moreover, although Bivariate analysis carried out as described above can provide some information, the picture provides by multi-variate analysis is of key interest in this study, as it is assumed that Critical Mass is characterized by a set of determinants that are jointly responsible for providing the

resources needed. Shedding light on the effect of these joint determinants on achieving objectives was the subject of the following regression analyses.

The final regression results presented here show those models that appear to yield the best explanations on achieving the six policy objectives. In these analyses, the levels of achievement of all policy objectives were studied, regardless of whether they had been established from the start or not. They included indicators that operationalizing the theoretical hypotheses, but excluded indicators that were particularly inter-correlated in the model. Moreover, the models included a few indicators that showed a high empirical correlation to the achieving the objective.

Table 6.6 Results of Regression Analysis: Determinants relevant for achievement of Critical Mass objectives

Dependent Variables: Achievement ratios for these policy objectives:	Addressing Socio-technological challenges	Addressing Scientific Challenges	Securing competencies for defensive reasons	Securing competencies for prospective reasons	Reaching excellence	Reaching self-sustained dynamics
Participants in ERA-NET	0.153	0.088	-0.041			0.215
Coherent motives of participants				0.259**	0.220**	0.403***
Joint Calls overall budget	0.237		0.141	0.153	0.100	
Av. Budget per Call		0.195				
Av. Number of Partners per Call	0.281*	0.484***	0.458***	0.534***	0.557***	0.361**
EC funding for ERA-NET coordination	0.184					0.270*
Effective ERA-NET coordination	0.262*		0.290**			0.095
novelty of anticipated results		0.281**		0.105	0.132	
orientation towards development	0.395***					
Av. Number of partners (beneficiaries) per project						-0.287*
Explained variance (Corrected r2)	0.38	0.31	0.35	0.40	0.37	0.45
Number of observations	40	44	46	44	44	36

Note: Cells list standardised beta coefficients. Statistical Significance: ***=at the level of 0.01, **=at the level of 0.05, and *=at the level of 0.10. See detailed results in the Annex.

First, these analyses confirmed our expectation that different profiles or combinations of determinants explain the type of Critical Mass i.e. achieving related policy objectives. The following overview reports the results of the ERA-NET analyses that proved to be statistically significant.

- The Critical Mass for **achieving the objective of addressing socio-technological challenges is generated by** the following combination and qualification of determinants and resources:
  - R&D projects with a clear development orientation

- A high number of partners[26] participating in ERA-NET calls
- The increase of highly effective coordination / management of the ERA-NET concerned
- A large budget allocated against an ERA-NET calls (*less relevant than the other factors, but which had minimal statistical significance*)

- The Critical Mass for **achieving the objective of addressing scientific challenges is generated by** the following combination and qualification of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - The existence of projects (expected to) lead to radically new results
  - On average, the allocation of a large budget for each ERA-NET call (*less relevant than the other factors, but with minimal statistical significance*)
- The Critical Mass for **achieving the objective of securing competencies for defensive reasons is generated by** the following combination and qualification of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - The highly effective coordination / management of the ERA-NET concerned
- The Critical Mass for **achieving the objective of securing competencies for prospective reasons is generated by** the same combination and qualification of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - A high consistency in the motivations of the individual ERA-NET partners
- The Critical Mass for **achieving the objective of reaching excellence is generated by** the following combination and qualification of determinants and resources:
  - A high number of partners participating in ERA-NET calls
  - A high consistency in the motivations of the individual ERA-NET partners
- The Critical Mass for **achieving the objective of reaching self-sustained dynamics is generated by** the following combination and qualification of determinants and resources:
  - A high consistency in the motivations of the individual ERA-NET partners
  - A high number of partners participating in ERA-NET calls
  - A smaller number of beneficiaries per research project *(this was an unexpected result and will be discussed below)*
  - A high amount of EC funding required to coordinate an ERA-NET

Interesting aspects and qualifications:

- Not the number of participants that are members of an ERA-NET is key, but the **number of participants who are in fact regularly active** and involved in the main activities of the ERA-NET.

[26] Partners in ERA-NETs are programme owners and managers, such as public administrations and agencies

- Likewise, what is important is the **overall amount of money pooled** together in ERA-NET calls, rather than the number of calls itself (although of course there is a positive relationship between number of calls and the overall call budget pooled by an ERA-NET).
- The **amount of money for calls** has been assumed to be relevant for all objectives, in particular for reaching excellence, while in fact it appears to be relevant mainly for addressing socio-technological challenges and scientific challenges.
- Effective **ERA-NET management** is important for addressing socio-technological challenges - as has been expected, but also for securing competencies for defensive reasons. Here, the indicator rating the overall effectiveness has a strong influence, while the coherence of activities is not important for achievement. In the case of achievements with respect to establishing self-sustained dynamics, another aspect of coordination is important. Here, achievements increase with higher amounts of **EC funding for ERA-NET coordination**.
- The **coherence of individual motivations** of ERA-NET partners appears as an important success factor for **securing competencies for prospective reasons**, **reaching excellence**, and as a most important factor in **achieving self-sustained dynamics.** As the coherence variable is negatively correlated to the variable that indicates whether relevant partners are missing in an ERA-NET, this finding means that when an ERA-NET is successful in having all relevant partners on board, this may be (indirectly) helpful in achieving the three Critical Mass objectives cited
- Although Critical Mass is often used as a synonym for reaching large scale or large scope, or at least hinting at increasing size at project or programme level, these results appear to give evidence that Critical Mass is not related to project size (in terms of partners), especially for addressing socio-technological or scientific challenges. We find, that for ERA-NETs striving to establish **self-sustained dynamics** of a scientific field, a **small number of beneficiaries per project** is an important determinant – contrary to what has been expected
- In addressing **scientific challenges**, projects leading to **radically new** results (or that are expected to) were found to be important. Bivariate correlations showed that this expectation was often linked to projects of longer duration

The strength of these results was judged as follows: the regression analyses made it possible to conclude that the combination of identified factors contributed to the ERA-NETs achievement of policy objectives. As these results came from a small sample however, they should be regarded with caution. For example, no conclusions can be drawn from these results about the quantitative threshold of resources needed, as the number of cases (between 36 and 46) is deemed to be too small for any such conclusions.

The overall explanatory power of the models however, produced a good and reliable range of values of between 31.1% and 45.1%. For this reason, the potential problem of omitted variables due to missing data on the beneficiaries, seems to be negligible.

Concerning theoretical assumptions regarding relationships, the results from testing the hypotheses were mixed:

- **Participants' involvement in the calls** (the more partners who participated in a call, the better) was relevant to addressing socio-technological challenges and self-sustained dynamics and to other objectives, whilst the overall numbers of partners in an ERA-NET was less so
- **Diversity of participants**: None of the diversity indicators had a direct link to achieving socio-technological challenges, but one did show a correlation to effective ERA-NET management. Effective ERA-NET management was shown to be an important factor in addressing socio-technological challenges
- With regard to the **motivations of individual partners**, this was found to help achieve policy objectives; the more **coherent** they are the greater the achievement, in particular in addressing self-sustained dynamics, but also excellence and securing competencies for prospective reasons. Therefore, whilst the diversity of participants may have some relevance (e.g. different country sizes), they should however agree on the ERA-NETs basic strategy and activities
- The **amount of money allocated for calls** was been assumed to be relevant to all objectives and in particular for reaching excellence, but in fact it appears to be relevant mainly in addressing socio-technological and scientific challenges. The amount of money for projects could not be tested separately as it was correlated to the call budgets. Here, the same hypotheses and the same results apply
- The **number of calls** was correlated to the call budget and as such, of most relevance to the two objectives mentioned above (as assumed), but not in reaching self-sustained dynamics
- **Novelty of anticipated results** was assumed to be an important determinant in addressing scientific challenges, the securing of prospective competencies and reaching excellence. Analysis in fact confirmed that it as an important element in addressing scientific challenges
- **Development orientation of projects** was shown to be an important element of the Critical Mass of resources relevant in addressing socio-technological challenges, which confirms the hypothesis
- **A small number of beneficiaries** was an important element of the Critical Mass of resources for reaching self-sustained dynamics – which was contrary to expectations. Furthermore, project size in terms of beneficiaries appears to have no relevance in addressing socio-technological or scientific challenges

- **Effective ERA-NET management** was, as expected, important in addressing socio-technological challenges, but also in securing competencies for defensive reasons. Self-sustained dynamics on the other hand are achieved in proportion to the amount of **EC coordination funding** available
- The relevance of the existence of complementary R&D activities or the diversity of coordination activities for any of the objectives could not be confirmed

In conclusion, an assessment must be made of how these results relate to those of the qualitative in-depth case study. The case studies of 13 ERA-NETs showed that the following determinants were often mentioned as having relevance in achieving or not achieving Critical Mass.

- The number and diversity of **partners** in ERA-NET was particularly relevant as was the presence of large European states.
- **Participants' involvement** in joint calls
- Opening towards **third party countries** was also considered to be a way to extending the scope and the scale of a programme and thereby reach Critical Mass. This also came up in several "Excellence" driven ERA-NETs.
- R&D activities, mainly **joint calls**. Often, very open calls, designed to complement FP7 or other European funding - in other words filling any existing shortfalls in international collaboration funding
- The **regularity of joint transnational activities** (yearly joint calls, almost yearly conferences) appeared to be a positive factor in the achievement of Critical Mass.
- **Non-R&D activities** were important for building mutual trust and commitment and in preparing R&D activities.
- **Small-scale projects:** many ERA-NETs set a maximum number of partners per project (e.g. 5).
- **Engaged ERA-NET management.**
- It can be concluded that the position of the **coordinator** in any one ERA-NET is of crucial importance to its success. Coordinators who saw no extra value in either the ERA-NET as an instrument or its objectives were major stumbling blocks to creating the necessary "drive" and subsequently, for achieving objectives related to Critical Mass. Coordinators are key players in these networks and their role in generating trust, understanding and commitment among the participants is vital
- **Pre-existing cooperation** at different levels and an alignment with policy and regulatory initiatives at global level often created a positive environment and were important factors to success.
- A **strong personal commitment** by the participants is believed to be crucial for the achievement of Critical Mass, at least from the organizational and coordination point of

view. They have to “battle” for the ERA-NET’s policy in their home organizations, thereby making national funding and other resources available

These findings **mostly confirm and qualify the quantitative analysis**. They give **particular weight to the role of participants and of the coordinator**. For example, they emphasize the need for participants to have pre-existing links to each other, or in the event this is not so, the need to focus on building trust and commitment, which can be done, for example, through the non-R&D activities of the ERA-NET. Participants need to be strongly committed to ERA-NET policy (i.e. their motivations should be similar) and the coordinator’s personal interests and his qualities as a manager play a crucial role.

7 The Relevance of Critical Mass and Coordination in international Research Policies and Programmes

In this chapter, we present the results of a comparative study of coordinated research programmes in the US and BRIC countries. The goal was to assess whether these countries show similar rationales for the creation of Critical Mass, what instruments these countries use to achieve this (compared to the ERA-NET scheme) and whether the definition of Critical Mass is valid in other contexts as well.

In order to identify Critical Mass in foreign contexts, we started out by screening national strategy documents. Even if rarely mentioned explicitly and never defined, objectives that can be addressed by pooling a Critical Mass of resources are relevant issues in all these countries. As a second step, we looked at the policies and programmes executed at federal level that try to coordinate or pool a set of individual and/or sub-national approaches. This step guaranteed their comparability to ERA-NETs.

This comparison – although limited to desk research –gives an illustration of the role that the idea of Critical Mass plays outside the EU. It showed that there are several similarities in Critical Mass objectives between the US and the EU / ERA-NET context. The BRIC countries have more focused approaches, as their technologies and economies are working on catching-up.

7.1 Introduction to the coordination of research policies and programmes in the USA and the BRICs

In the previous chapters, different ways of understanding the concept of Critical Mass in the context of research policies were discussed in the context of ERA-NETs. Critical Mass is considered to be a threshold of resources necessary to achieve a certain objective for which different types of resources become relevant, depending on the objective. The empirical data and cases studies on selected ERA-NETs showed that the indicators support the suggested definition of Critical Mass. This chapter of the final report explores another avenue, and puts the ERA-NET experiences into a comparative perspective with countries outside the EU. It summarizes the main findings of the study on initiatives for coordinating research policies and programmes in Brazil, Russia, India, China and US.[27]

The core of the country chapters focuses on the aspect of coordinating research policy. This chapter provides an aggregate analysis that is first and foremost focused on the relevance of Critical Mass in those countries' research policies.

[27] The whole study on the US and the BRIC countries can be found in the Annex 3 of this report.

It should be stated at the beginning that there is no instrument comparable to the ERA-NET scheme in the BRICs Countries or the US. The ERA-NETs are a genuine EU initiative that is not applicable in other national context on a like for like basis, as its main features are transnational policy coordination and joint funding mechanisms of research, explicitly by more than one country. Transnational cooperation unarguably entails more obstacles and is more difficult to implement as it involves the possible diverging interests of a given number of partners. Therefore, it should be made clear from the start, that the comparison is not about the ERA-NET scheme as such, but more about the ways that other countries and world regions employ to generate Critical Mass and/or to avoid fragmentation and duplication.

Although the European Union and the five countries included in the comparison might well be viewed as multilevel systems, they are obviously significantly different with respect to the degree of centralisation of policies at federal/supranational levels. The history of European integration is all about the effort to harmonize or centralize different national policies where the objectives to be addressed are too large or require too much effort to be reasonably addressed by the efforts of individual countries alone. The political system of the USA shows a similar degree of decentralisation of policy competences. In contrast, Brazil, Russia, India and China all have historically developed top-down structures. While the approach of the European Research Area (ERA) is to create Critical Mass in order to achieve research and innovation policy objectives better, this tendency for centralisation is not the same in all the countries analysed. We found aspects of a centralising or integrated coordination of efforts in the US, Russia and India, while China and Brazil currently also show attempts to decentralize policies in order to strengthen regional development.

Another challenge for the comparison was the heterogeneity of the group of countries. While the US can be considered a major competitor in terms of scientific development, in respect of the EU, the BRIC still have a clear disadvantage. However, during the course of the last decade, these countries have been building up their scientific and innovative capacities and tried to complement their economic growth potential that was initially based on static competitive factors such as cheap labour (India and China) or natural resources (Brazil and Russia), with more technological and science based factors. In this respect, it also needs to be acknowledged that the BRICs are by no means a homogeneous group of countries (Armijo 2007) and each of them has different strategies and focus areas. The approach by India and Brazil for example is much more orientated towards social development (science as a means to solve social challenges such as poverty, mal-nutrition, health, etc.) than China.

Finally, a serious challenge for the comparison was the lack of comparable data. Desk research allows for the screening of available publications and accessing publicly available databases. However, official data in some countries must be regarded with some degree of scepticism, as in the absence of scientific evaluations, it is likely to have been whitewashed. The study was also limited because it was not possible to generate primary data or to conduct interviews with policy makers and other stakeholders in the selected countries. Without a doubt, this step would have

yielded more in depth insights into the rationales of EU competitors and it would have been possible to compare the results of the European study on Critical Mass with the programmes and instruments used elsewhere. While this has to be left for future research, the present study was limited to desk research.

However, despite the wide range of difficulties there are several starting points for a comparison to be made with the ERA-NET scheme and the output of the Case studies. All countries aim to support their science and technology sectors in order to reach some of the objectives that were defined as being related to Critical Mass in this report. All countries analysed here have, at the very least, national research programmes that aim to contribute to socio-technological and scientific challenges. There were also signs of programmes for excellence and self sustained dynamics.

Therefore, and in order to deal with the above-mentioned difficulties, a multifaceted view on the countries was employed that took into account current national science and technology plans and secondary literature. The goal of this literature review was to identify the policy measures of the respective countries that aim to create Critical Mass.

In order to guarantee a certain degree of data comparability, we analyzed Trendchart Country reports and opted for the Erawatch policy measure database to identify individual measures at programme level to see whether they show a notion of Critical Mass or interesting forms of coordinating research policies or programmes. It must to be mentioned however, that the list of programmes is far from complete. Because of the sheer mass of programmes, the following chapters include a selection of programmes that appeared worthy of mention in the context of this study.

7.2 The USA

The US economy, with a population of about 300 million, is now clearly smaller than the EU-27 with approximately 500 million inhabitants, but it is about 50 % more productive than the heterogeneous European economy with a GDP per capita at 45,000 US$ compared to about 30,000 US$ in the EU. The composite indicator from the European innovation scoreboard indicates that the innovation performance of the US exceeds that of Europe by 22 % (see table 7.1). R&D expenditures were at 2.6 % of the GDP in 2006. In absolute terms, the US is the country with the highest R&D expenditures worldwide.

Policy setting of the R&D agenda at federal level comes through the budget process. R&D priorities are typically set by federal agencies based on their specific missions. Federal departments and agencies with the most substantial R&D expenditures include the Department of Defence (which comprises roughly half the US R&D budget), the Department of Health and Human Services, NASA, the Department of Energy, and the National Science Foundation. Memoranda are used to guide the coordination of R&D priorities between these and other agencies, issued by the Office of

Management and Budget, the Office of Science and Technology Policy and the National Science and Technology Council.

Table 7.1 Indicators for the US at a glance

Population (Head count, 2007)	302 mill.
GDP per capita (2007)	45,488 US$
GDP growth rate (2007)	2.0 %
Unemployment (2007)	4.6 %
R & D intensity (GERD/GDP, 2006)	2.61 % of GDP
Share of private sector R&D (2006)	70.3 % of GERD
Share of public sector R&D (2006)	25.4 % of GERD
Innovation Performance (innovation gap)	+22 % compared to EU-27

Sources: OECD, Science and Technology Indicators from ERAWATCH, Innovation performance data from EIS 2009.

The main instruments[28] used to implement research policy include generic R&D policy towards the public sector (e.g. competitive grants, large awards to create research centres), generic R&D policies towards the private sector aimed to fulfil mission-specific research, and funding of multi-institutional, multi-disciplinary centres of excellence or research consortia. Generally, the basic rationales of the US research and innovation policy clearly address the notion of generating Critical Mass – albeit not always in explicit terms. However, the mission-orientation of the US policy, in particular the turn of the Obama administration towards societal challenges such as climate change, energy consumption, mobility, health care and the like, implies pooling a Critical Mass of resources. This is also true for the excellence orientation inherent in US research and innovation policy.

The US funding system for R&D is highly decentralized and shared among multiple departments and agencies. The departments and agencies are running their own funding programmes according to their individual missions. In addition to this horizontal decentralisation, there is also a vertical sharing of competencies between federal and state levels with the latter having individual innovation policy goals and measures. The coordination between the different players is not as highly centralized as in other countries (like China), mainly because the US funding system resembles the features of a federal political system.

Observers of the US innovation governance have seen a trend "in interagency partnerships and coordination at the level of the executive departments and agencies."[29] The most prominent instrument in this context is the National Nano-technology Initiative (NNI). The **National Nanotechnology Initiative** (NNI) is a cross-agency umbrella initiative that develops and coordinates R&D activities, participates in the setting of budgets, federal policies, and technology transfer. The National Institutes of Health **NIH Blueprint for Neuroscience Research** is a second

[28] Youtie, "Main instruments in research policy" and "Interaction between Innovation and Research Policies", ERAWATCH (2010).

[29] Shapira and Youtie ("USA", 2008, 20).

example for the coordination of individual agencies' efforts and budgets in order to address societal and scientific challenges.

Compared to the ERA-NET scheme, the NNI does not involve sub-federal actors, but is a horizontal activity at federal level, involving departments and agencies with nano-technology R&D budgets (and some without any budget). According to the information available, it seems to be the case that the NNI coordinates the full budgets of the participating institutions for this sector, which is currently at 1.36 billion € per year, while in ERA-NETs, the partners can commit a certain share of their funding. The NNI clearly aims at reducing the duplication of research and making a better (synergetic) use of infrastructures. The level of the calls remains national, so the motivation to open access to new research communities (in other countries) is not applicable to the NNI.

In 2005 a mid-term review by the President's Council of Advisors on Science and Technology (PCAST)[30] has drawn several conclusions which reflect that the NNI is based on objectives similar to those of ERA, hence there is an implicit approach to reach Critical Mass to contribute to the following objectives – for some of which there is some evidence of achievement:

- The NNI has taken steps to address societal concerns, e.g. environmental, health, safety,
- There is a scientific challenge: exploring the potential application of nano-technology to different fields (and there is evidence of publications and patents addressing it)
- Excellence / securing a level of competence for defensive reasons: "Today, the United States is the acknowledged leader in nano-technology R&D. Our leadership position, however, is under increasing competitive pressure from other nations as they ramp up their own programmes"
- The study spells out the need to increase coordination with the states (who are offering additional R&D funds to nano-technology), which would also increase similarity with the ERA-NET scheme.

The NIH Blueprint for Neuroscience Research is a cooperative effort among the 16 NIH Institutes, Centres and Offices that support neuroscience research. By pooling resources and expertise, the Blueprint identifies cross-cutting areas of research, and confronts challenges too large for any single Institute. Compared to the ERA-NET scheme, the NIH blueprint does not involve sub-federal players, but is a horizontal activity at the federal level, involving the relevant medical institutes for neuroscience research. Similar to ERA-NETs, the partner institutes commit funding to a common pot, in order to support common research needs. The NIH blueprint has the mission to address challenges that are too big to be tackled by institutes' individual approaches. In the calls, non-domestic (non-U.S.) entities are also eligible for funding. However, the whole measure is not being flagged as a means to increase international collaboration. There is no study yet about the impacts of the measure.

[30] PCAST (2005) "The National Nanotechnology Initiative at Five Years".

There are other initiatives at central level in production technologies (Manufacturing Extension Partnerships), Behavioural Sciences (Basic Behavioural & Social Science Opportunity Network, also by the NIH), and the Clean Energy States Alliance. These efforts are still either too young to be assessed or is non-existent and little dedicated effort has been made to research or the pooling of research funding. Moreover, there are cross-state or regional coordination initiatives, which are to a lesser extent pooling research funding, mainly with the aim of supporting the general economic development of the regions rather than with specific research policy objectives.

7.3 Brazil

The Federal Republic of Brazil consists of 26 states and a federal district, and a little over 190 million inhabitants. The second government of former President Luis Inácio "Lula" da Silva was somewhat successful in dealing with some of the country's most pressing problems such as fighting poverty and a pervasive inequality of income. Economic growth was stable but moderate with an average growth rate of 4 % between 2000 and 2008. The economic dynamics were spurred by internal dynamics and favourable external conditions. Being an export-oriented economy, Brazil's external trade was hit by the global downturn in 2008/09 especially because of falling prices for low-scale manufactures and primary goods. Compared to the OECD countries, Brazil remains a low R&D performer. The country spends roughly 1.1 % on S&T. There has been a significant rise in expenditures in the last few years in absolute terms, but taken together the innovative capacity of Brazil is comparatively low.

The Ministry for Science and Technology (MCT) is the most important formal player in ST&I policy-making. Due to its cross-cutting character, almost all other relevant ministries have some sort of support programme in the area of ST&I, most notably the Ministry of Education (MEC), which is responsible for higher education including the universities. The Ministry for Industry and External Trade (MDIC) that is responsible for defining the Industrial, Technological and Foreign Trade Policy (PITCE) is also very influential.

Table7.2 Indicators for Brazil at a glance

Population (Head count, 2008)	192 Mio.
GDP per capita (2008)	10,465 US$
GDP growth rate (2008)	5.07 %
Unemployment (2008)	7.3 %
R & D intensity (GERD/GDP, 2008)	1.13 %
Share of private sector R&D (2006)	ca. 45 % (incl. State owned firms)
Share of public sector R&D (2006)	ca. 55 %
Innovation Performance (innovation gap)	-55 % compared to EU-27

Sources: OECD Country statistical profiles 2010, R&D statistics from OECD and Brazilian Ministry of Science and Technology (MCT), Innovation performance data from EIS 2009.

The various ministries and institutions traditionally lack interaction and ministerial co-operation tends to be difficult (Stehnken 2010). According to Botelho (2009), the political system has not fully kept up with the changes in requirements for ST&I policy. This is true especially with regard to the newly required set of institutional arrangements among key players and organizations, such as the increased needs for monitoring and evaluation, the innovation-specialized human resources and the sharing of accountability (ibid.).

The Brazilian Innovation System experienced a considerable growth due to the expansion of public funds in recent years. The PACTI 2007-2010 was the most massive investment programme in the history of Brazil's ST&I-System. The PACTI aims to spend roughly R$ 41 billion (approx. 14.3 billion €) on S&T during the 2007-2010 period by joining the efforts of several ministries and other public institutions. During this period, many public programmes for coordinated research were either expanded, re-designed or built up from scratch. However, even though there are numerous programmes, countless incentives and public research organizations in all kinds of specific areas, the overall innovative performance of Brazilian firms remains low.[31]

Interestingly the strategy document for PACTI mentions "Critical Mass" explicitly as one of the guiding principles of future strategy.[32] The term is not defined at all, but is used to describe the growth of the S&T system over the year, mainly referring to the current 85,000 high-level scientist and engineers who carry out scientific and technological research of international importance, and the growth in the output of scientific publications. These developments reflect a strong growth in Brazil's academic base. In the Brazilian context, the notion of Critical Mass therefore, mainly refers to a scientific or socio-technological challenge and is usually measured in term of publications and scientific awards or new products and processes.

Brazil has horizontal as well as thematic programmes for coordinated research. The main agency for horizontal activities that supports innovation and technological upgrading is the Brazilian Innovation Agency **FINEP** (*Financiadora de Estudos e Projetos*). FINEP manages a wide variety of support lines which are in need of an extensive and long overdue review and simplification (de Morais 2008; Salerno and Kubota 2008). FINEP coordinates its instruments (credit lines, subsidies, non-reimbursable resources, venture capital) with the respective ministries and available funds come from ministries as well as various taxes and duties. In this way, FINEP acts as an umbrella organization in the Brazilian Innovation System. Its counterpart for purely academic science is the CNPq, the Brazilian Research Council.

Relatively new, but very important institutions in Brazil are the so-called **Sectoral Funds** for S&T (*Fundos Setoriais para Ciência e Tecnologia, FS*) that were implemented from 1999 onwards. Their goal is to overcome the structurally lacking connections between public and private R&D activities

[31] Arbix (2007), de Morais (2008)

[32] Principle 4 of the PACTI states that "Brazil is in an "intermediate" position in the world in terms of productive and academic capacity, but has the "Critical Mass" necessary to gradually draw closer to the technological levels of developed economies" (Ministry of Science and Technology 2007: 18).

by guaranteeing long-term and stable financing. The rationales of the FS scheme are highly comparable to those of ERA-NETs. The Sectoral Funds have become the most important support programmes for the creation of Critical Mass in terms of social-technological challenges and securing competencies. Each FS has a different revenue formula and can only finance research of interest to the sector committees (*comitês gestores)* that comprise government, academic and private sector representatives. Since their creation in 1999, approximately R$ 2.3 billion (ca. 765 million €) were distributed to universities and public research institutes to finance research projects independently of private sector participation (de Negri et al. 2008, 294).

One example of a federal coordinated research programme is the **Life Science Biotechnology Competitiveness Programme** whose aim is to encourage technological development and innovation in strategic biotechnology sectors, such as agriculture, human and animal health, and the environment. The Biotech Programme was introduced in 2007 and shows certain similarities when compared to the ERA-NET scheme as it calls for the coordination of several ministries. Sub-national cooperation occurs on an individual basis. There is also cooperation with Argentina; to date however, the calls remain on a national basis. Output indicators show that the programme has a considerable effect on networking, scientific achievements and the commercialisation of research results.

Moreover, there are coordination initiatives or regional policies, which include the coordination of S&T initiatives, mainly with the aim of supporting general economic development of the regions rather than with specific research policy objectives.

In the case of Brazil, it is important to note that there is a long history of stakeholder involvement in S&T policies. While certain groups (especially the scientific community) were able to influence the outcome of the discussions significantly in the past, the two most recent conferences allowed civil society groups to participate more vigorously. This led to a better coordination of policies due to higher accountability and awareness on all sides (Stehnken 2010). The 4th Conferência Nacional de C,T&I (CNCTI) was conducted in 2010. The results of this conference entered the new PACTI 2011-2015 (Livro Azul, Blue Book), which was published in late December of 2010. The document went through three rounds of amendments, including a public discussion via an internet forum.

7.4 Russia

The Russian Federation with its 141 million inhabitants has the seventh largest GDP in the world. Despite dynamic growth between 2002 and 2006 the GDP per capita is about 13,000 US$ compared to about 30,000 US$ in the EU27. The Russian Federation surpasses the EU27 countries in terms of the GDP growth rate: in 2008 the GDP of Russian Federation annually grew by 5.6 % while in Europe it remained at 0.8 %. GDP growth and employment trends (7.1 % for EU27 and 6.1 % for the Russian Federation) look better than corresponding indicators of average economic performance for the EU27 (Ivanova et al. (2007).

Table 7.3 Indicators for Russian Federation at a glance

Population (Head count, 2008)	141 mill.
GDP per capita (2006)	13,217 US$
GDP growth rate (2008)	5.6 %
Unemployment (2007)	6.1 %
R&D intensity (GERD/GDP, 2008)	1.03 % of GDP
Share of private sector R&D (2009)	11 % of GERD
Share of public sector R&D (2009)	>70 % of GERD
Innovation Performance (innovation gap, 2009)	-29 % compared to EU-27

Sources: OECD country profiles 2010, Science and Technology Indicators from ERAWATCH, Ministry of Science and Education of the Russian Federation, European Innovation Scoreboard (EIS) 2009.

In the Russian Federation, most of the policy decisions such as programmes' definitions are centralized. Coordination of different national bodies represents the normal way for doing research in the Russian Federation. In 2006, President Vladimir Putin defined the *Priority areas of development of science, technologies and machines and equipment in the Russian Federation*[33]*:* safety and the prevention of terrorism, living systems, industry of nano-systems and nano-materials, information-telecommunication systems, prospective armaments, military and special-purpose machines and equipment, rational nature management, transportation, aviation and space systems, power engineering and energy saving. The highest amounts of financial and human resources are currently concentrated in these technological fields at national level.

Federal Target Programmes (FTP) seem to be the most remarkable programmes for coordinated (thematic) research in the Country. Some examples of FTP are: "Development of Nano-technology Infrastructure in the Russian Federation for 2008 – 2010", "World Ocean", "National Engineering Capability for 2007–2011", "Development of Electronic Component Base and Radio Electronics for 2008 – 2015", "Scientific and Scientific-Pedagogic Cadres of Innovation Russia for 2009–2013".

The Russian Federation is constantly developing effective international cooperation for the R&D sectors of these and other areas. Russia is an Associated Country in the EU's Framework Programme for Research and Development (FP7) and it participates in the Technology Platforms in Life Sciences and Agriculture.

In recent years, Russian research and development areas experienced a noteworthy growth thanks mainly to institutional incentives. In 2005, 10 National Information Analytical Centres (NIAC) were established within the framework of the Federal Target Research Programme - *"Research and Development in Priority Areas of Science and Technology Development in Russia for 2002-2006".* The programme was aimed at monitoring the priority areas in science and technology development, innovation structure of science and engineering activity and regional innovation systems, training personnel for research and innovation activies and ensuring their mobility.

[33] Approved by Vladimir Putin, President of the Russian Federation on May 21, 2006.

In 2006, the Interdepartmental Commission for Science and Innovation Policy, chaired by the Minister of Education and Science adopted the *Comprehensive Programme for the Scientific-Technological Development and Technological Modernisation of the Economy of the Russian Federation up to the year 2015*. The medium-term objective of the programme is formulated as follows: "... the formation of a balanced R&D-effective innovation system sector, providing the technological modernization of the economy and enhancing its competitiveness through advanced technologies and transformation of scientific potential in one of the major resources for sustainable economic growth." Among the tasks expected to be resolved in the framework of the Strategy, the most important are:

- Creating competitive R&D sector conditions for expanded reproduction
- Development of an effective national innovation system
- Establishment of R&D institutes resulting in legal protection
- Modernization of the economy through technological innovation

This 2006 initiative laid solid foundations to the actual *Governmental Commission on High Technologies and Innovations,* established in 2007, whose role is to support the 2015 Comprehensive Programme by coordinating research policy. This governmental body illustrates the current overall priority that the Russian top leadership puts on the modernisation of the economy through R&D based innovation. The commission is chaired by 40 representatives drawn from many public sector institutions in the Russian research sector, whose main task is to advise the government on research policy and which relative direction to adopt. This Commission and consequently the incentives in Russian research policy benefit from crucial support such as the Minister of Education and Science, Minister for Economic Development, President of the Academy of Sciences, Rector of Moscow State University and the Head of the Russian Space Agency, as well as heads of research funding bodies.

Research programmes in Russia are therefore mainly funded publicly from the federal budget. The Russian government, in close cooperation with the Commission on High Technologies and Innovations, regularly launched new competitive funding programmes named Federal Targeted Programmes, in order to stimulate specific thematic priorities.

The programmes that are laid out in detail in the Annex focus on **socio-technological challenges** and to a lesser extent, on **scientific challenges** inasmuch as the programmes aim to create new knowledge and new research fields. This is especially true for the Nano-scientific programmes but also the Glonass-Satelite programme. Overall, the rather centralized Russian support system shows various signs of transforming Russia into an innovative economy. Much of the funding is therefore also devoted at securing **competencies in a prospective sense**.

7.5 India

The federal republic of India consists of 28 states and 7 union territories and has a population of more than 1.1 Billion. India's economy has been growing at an impressive average annual rate of more than 8 % between 2000 and 2009. The global financial crisis of 2008/09 brought a slight downturn of this dynamic, but still the economy grew by 6.7 %, which makes India one of the fastest growing economies next to China – despite pressing problems such as significant overpopulation, environmental degradation, extensive poverty, and widespread corruption. Given these challenges, the government focuses on macro and micro economic and social problems associated with the "bottom of the pyramid".[34]

Table 7.4 Indicators for India at a glance

Population (Head count, 2008)	1,144 Mio.
GDP per capita (2008)	2,779 US$
GDP growth rate (2008)	7.34 %
Unemployment (2008)	n.a.
R & D intensity (GERD/GDP, 2008)	0.88 %
Share of private sector R&D (2006)	ca. 30 %
Share of public sector R&D (2006)	ca. 70 %
Innovation Performance (innovation gap)	-58 % compared to EU-27

Sources: OECD Country statistical profiles 2010, R&D Statistics from OECD and ERAWATCH, Innovation performance data from EIS 2009.

India's innovation policy is characterized its large range of issues because it finds itself at the crossroads of becoming a "developed country sooner or later" (Department of Science & Technology/Ministry of Science & Technology 2010: 7). Policy therefore, has to address several issues at the same time: help solve societal challenges (e.g. rural poverty), try to gain knowledge in future technologies with high market potential (e.g. bio-technology or nano-technology) and competing with world-class research facilities located outside its borders in the industrial countries. The current 11th Plan for Science and Technology for the 2007 – 2012 period acknowledges this situation and gives a broad spectrum of policy rationales and guidelines for the direction of R&D activities (Government of India 2006). With reference to the industrial countries, the document emphasizes the need to catch up in the technological fields developed by the industrial countries, and to complement them with an Indian perspective. Self-directed basic research should receive substantially increased support.

The plan makes two explicit references to Critical Mass without defining the term. First, it states that academia lacks a Critical Mass of experts and a specialized technical infrastructure to collaborate with industry. Critical Mass in this context refers to the gathering of an overall amount of researchers. India does not dispose of enough researchers to conduct excellent basic research

[34] WTO (2010), Krishna (2009)

at universities and applied research for industry at the same time. The second aspect refers to institutional factors. Apparently, in the case of bio-technology the country does have a "Critical Mass" of researchers, but they cannot find a favourable research environment in their national institutions. In others words, the effects of Critical Mass are hindered by institutional shortcomings.

While some sectors of the Indian Economy are recognized at a worldwide level ("technological islands") others are lagging far behind. The 11th Plan envisages that India must try to become a "Global Innovation Leader" across all S&T areas and highlights the objectives and challenges for achieving a broad-based higher economic growth rate in agriculture, industry and services, as well as the measures required for a more inclusive development. This balancing act of developing first-class knowledge to compete on a global scale, and at the same time catering for technological social inclusion is the main challenge for the Indian Innovation System at the moment.

In India, the central government has always played an important role in the development of the national industrial sector. On the one hand, there are clear signs of widespread **mission orientation.** The reasons for this have to do with the country's deep societal challenges such as poverty, malnutrition and urbanization. The aim is to expand the Mission-mode and multi-partnership projects between S&T players, industry and the ministries - the socio-economic ones in particular - both quantitatively and qualitatively. One example of mission orientation is the recently started "WAR on Water mission" (Winning, Augmentation and Renovation of Water resources) of 2009.[35]

Other mission-oriented programmes include the **Solar Energy Research Initiative[36] or the Nano-initiative**. Some programmes fall within the scope of the socio-economic ministries but if the programmes are to be successful, the existing modes of interaction between S&T systems and the socio-economic ministries must be improved. Coordination of programmes has been an issue in the past, as both spheres have been working in a somewhat isolated fashion.

That said, India has a tendency to establish Centres of Excellence (CoE) in various domains. Since India is not a world leader in any field, it aims to build up the necessary competencies and capacities in selected areas – whether it is in agriculture, export, in certain technology sectors (Bio-technology, Nano-technology) or in the industrial field.

As a federal country, there is a strong need for policy coordination between federal and state levels in India. The states have State Councils for Science & Technology that have now been set-up in all the States and Union Territories. This requires various consultations that result in joint programmes focusing on multi-sectoral approaches to rural and regional development. Those approaches that could significantly improve existing socio-economic conditions may also receive funding from various federal departments including DST.[37] There are other initiatives at a central

[35] http://dst.gov.in/scientific-programme/plan-document.pdf <15.01.2011>
[36] http://dst.gov.in/scientific-programme/t-d-solar-energy.htm
[37] http://dst.gov.in/scientific-programme/s-t_scst.htm

level in Biotechnology, the Climate Change programme, or the Mega Facilities for basic research. These efforts have not (yet) been assessed.

7.6 China

China's economy is still growing rapidly. Growth here was also been hampered by the worldwide recession in 2008, but is still remarkably high. Compared to other BRIC countries, China has the fastest growing and catch-up economy. Investment in R&D activities increased in 2008 and is now at 1.49 % of GDP.[38] China has been increasing R&D expenditure since the 1990s, and it overtook Japan in 2005 as the second largest investor in R&D, second only to the USA.[39] In China's Medium- and Long-Term S&T Development Plan, the government's R&D intensity targets were to reach 2.0 % in 2010 and 2.5 % by 2020.[40]

Table 7.5 Indicators for China at a glance

Population (Head count, 2010)	1,337 mill.
GDP per capita (2009)	6,567 US$
GDP growth rate (2008)	9%
Unemployment (2009)	4.3 %
R & D intensity (GERD/GDP, 2008)	1.49 % of GDP
Share of private sector R&D (2008)	71.1 % of GERD
Share of public sector R&D (2008)	28.9 % of GERD
Innovation Performance (innovation gap)	-25 % compared to EU-27

Sources: International Monetary Fund (GDP per capita), Trendchart (GDP growth rate, Science and Technology Indicators), Innovation performance data from EIS 2009, CIA World Factbook (Unemployment).

China's innovation system can be characterized as a top-down structure. Players performing intermediate-level functions are highly dependent on central political steering. There is hardly a subsystem of intermediate-level players with a degree of independence comparable to other innovation systems.[41] Since the Chinese economy has started to open up to market mechanisms, there is also a development in the innovation system towards greater decentralisation and research institutions are being given more authority to set their own research activity agendas. Research institutes and universities carry out most of the research, although this is concentrated in a few flagship sites and the vast majority of universities concentrate on teaching.

The main player in the Innovation system is the Ministry of Science and Technology, which is the leading ministry in S&T policy design and also the main implementation unit. The ministry coordinates S&T programmes and provides funds to R&D activities. Another important player is the National Natural Science Foundation of China that also has a programme management

[38] Tang, *China-Trendchart*, (2009); EIS 2009.

[39] Tang, "Basic characterization of the research system", ERAWATCH (2009).

[40] Tang, "The relative Importance of Research Policy", ERAWATCH, (2009).

[41] This kind of representation has its origins in the graphical illustrations of the national innovation system concept by Kuhlmann and Arnold, *Norwegian Innovation System*, (2001).

function. Finally, the Chinese Academy of Sciences is another important executive agency that manages over 80 research institutes and is the major research performer in China.[42]

Public research organizations conduct not only basic research, but are also active in the applied field. However, the overall research performance of the business sector "is still lagging due to the historical production-orientation of industry in China. However, the transformation of state-owned research institutes into enterprises, starting from 1999, has strengthened R&D capabilites in industry."[43] In order to encourage R&D activities and promote technology transfer and commercialisation, high-tech zones and incubators have been established, inspired by the Silicon Valley model in the US. Universities and research institutes create spin-off companies, through which they commercialise technology and the R&D products developed in their research labs.[44]

China´s technology policy is geared towards one paramount objective: **economic growth**. At the present state of development, this explosive growth is associated with low and middle tech export-oriented industrialization (Liefner 2008, 4f.). The goals of research policy in the next few years are specified in two major policy documents: the Medium- and Long-term National Plan for Science and Technology Development 2006-2020, and China's National S&T Development Plan for the 11th Five-year Period 2006-2010 (and its successor for 2011-15 respectively).[45] The 15-year-plan in particular can be seen as promoting a change in understanding of innovation, shifting from a linear understanding of innovation processes to a more interactive, systemic view of the process. "In essence, the new policy document mirrors the determination to move from a comparatively uncoordinated, piecemeal style of STI policy-making to a better coordinated whole-of-government policy approach."[46]

The policies and programmes analyzed in the annex, note the existence of the objective to reach "**self-sustained" dynamics"** in a field. There are also a number of indications that the Chinese research and innovation policy is addressing further Critical Mass objectives, such as national/**societal challenges** (sending a Chinese national to the moon) and **excellence**. Another example is the Joint Funds of the National Natural Science Foundation, which coordinate governmental, local and industrial funds. Like the other countries in this comparison, there are also some Chinese examples of the coordination of cross-regional research funds, however, the primary goal here is also to support regional development.

[42] Tang, "Actors in policy implementation ", ERAWATCH, (2009).

[43] Tang, "Basic characterisation of the research system ", ERAWATCH, (2009).

[44] Tang, "Interaction between Innovation and Research Policies ", ERAWATCH, (2009); see also Kroll et al., "China", (2008); OECD, *China*, (2008, 99ff.).

[45] Tang, "Main aims for research policy", ERAWATCH, (2009).

[46] Kroll et al., "China",(2008, 219f.).

7.7 Main insights

The comparison of the general trends of coordinated research programmes in the BRICs and the US showed several **similarities** with the EU in terms of programme orientation, the direction in which research is being steered and spending priorities. In terms of thematic orientation, all countries have their focal points, mainly in the life sciences. Another dominant angle is the focus on key technologies, in particular Nano-science.

However, as stated above, it is difficult to compare these purely national programmes that often involve large amounts of money for a certain national mission with the ERA-NET scheme as such, and the amounts being raised in the EU ERA-NETs. Coordination in these research programmes mainly refers to the coordination among ministries (especially regarding cross-cutting fields such as Bio-technology or Nano-technology) or to the coordination efforts with sub-national units often without thematic focus, but with the intention to employ S&T advancement as a means to contribute to regional development and the economic catching up process.

Also all countries have their respective spending priorities. Coordination mainly occurs by purely by steering input - different departments join forces and set up "programme families". The research activities of Centres of Excellence, universities or private players are ultimately geared towards these programmes because there are funds available.

A trend in most of the countries analysed, pointed to an **orientation towards academic excellence**. Most of the identified programmes are geared towards raising the number of patents or articles in their respective fields. The creation of basic knowledge or the formation of young researchers is at the heart of many of the programmes analyzed here. These patterns seem to be largely in line with the EU research support system.

On the other hand, however, there are considerable **differences** between the support mechanisms elsewhere on the one hand and with the ERA-NETs on the other. The amounts raised in the respective national contexts are much higher than the (virtual or common) pots under the ERA-NET scheme, which are shares of the participating countries' national budgets. Another difference concerns the rationales for coordinating research policies. While it is true that many programmes tend to support only excellent research, it is also true that in some countries coordinated research takes place to solve structural social challenges that have to do with the realities of developing countries. There are two emblematic cases in this regard - India and Brazil. Both of these countries devote considerable resources from various ministries and political levels to horizontal as well as thematic research activities that aim to alleviate poverty. Some of these activities result in actual growth industries (such as the generic drugs sector) while others focus on the application of high-tech to precarious living situations (for example installing solar panels for the electrification of rural areas).

Last but not least, there are different forms of research coordination. While Brazil and India show various forms of bottom-up approaches that includes large groups of stakeholders in the design of governmental strategies, the Chinese case shows considerable top-down structures. The US also

employs mechanisms to ensure that there is an involvement in certain research programmes at State level too, but its first focus is on the bundling of defragmented resources at national level. In the case of Brazil, there also is empirical evidence that the inclusion of stakeholders from local and state levels contributes to the outcome of policies and the accountability of strategies.

With regard to the countries in question, it can be concluded that **US** research and innovation policy clearly address the notion of generating Critical Mass – albeit not always in explicit terms. However, the mission-orientation of US policy implies pooling a Critical Mass of resources. This is also true for the excellence orientation inherent in US innovation policy. In some instances, there is also evidence available that documents success and impact. More specifically, single initiatives follow specific objectives. The National Nano-technology Initiative, for example, addresses socio-economic and scientific challenges from the same approach, but above all, it aims to secure the US a leading position in the field. It can be assumed that a wider recapitulation of US research and innovation policies would arrive at the conclusion that **all objectives related to Critical Mass play a role**, i.e. also those relating to very young research fields or small/ unconnected research communities.

In the case of **Brazil,** it was shown that the goal of coordinated research is to expand, modernize and consolidate the national innovation system and to increase innovation efforts in areas of strategic national interest. Most programmes need to be seen in the light of the new Industrial, Technological and Foreign Trade Policy, which aims to increase Brazilian added value in international trade. Another factor that must not be underestimated is Brazil's effort to universalize access to science and increase the diffusion of technology for better living conditions – so science will become increasingly important in social development. In this respect, many policies are coordinated with the sub-national level. The overall innovation strategy is the result of a long and very far-reaching consulting process with societal stakeholders through local, regional and rational Conferences for Science and Technology. In terms of Critical Mass-Analysis there is significant evidence that the following objectives are being addressed: **Socio-technological challenge, Securing competencies/ prospective and Self sustained dynamics.**

Russia is an example of a rather centralized system. Even though the regions show a large degree of autonomy, most of the policy decisions, such as the definition of programmes, are centralized in Moscow. Research programmes in Russia are therefore mainly publicly funded from the federal budget. The priority areas mark those fields that unite the largest amount of financial and human resources at national level. In these and other areas, the Russian Federation is constantly developing effective international cooperation for the R&D sector. In the case of Critical Mass analysis, the Federal Target Programmes (FTP) seem to be the most interesting programmes for coordinated (thematic) research. The programmes focus on **Socio-technological challenges** and to a lesser extent on **scientific challenges** in that the programmes aim to create new knowledge and new research fields. This is especially true for the Nano-scientific programmes but also the Glonass-Satelite programme. All in all, the rather centralized Russian support system shows

various signs of transforming Russia into an innovative economy. Therefore, much of the funding is also devoted at **securing competencies in a prospective sense.**

When summarizing the **Indian** case, it must be acknowledged that the current innovation policies and coordinated programmes have to address several issues at the same time. These include helping to solve societal challenges (e.g. rural poverty), trying to gain knowledge in future technologies with high market potential (e.g. biotechnology or nanotechnology) and to compete with world-class research facilities outside its national borders in the industrial countries. There is a need to catch up in traditional technological fields and adapt them to the Indian reality. There are clear signs of widespread mission orientation. The reasons for this have to do with the country's deep societal challenges such as poverty, malnutrition and urbanization. At the same time, India has a strong tendency to establish Centres of Excellence in various domains. One of the most compelling features of the Indian innovation Programmes is the focus on poverty alleviating aspects. Many federal efforts are devoted to academic excellence and frontier research; however, there are also various programmes that aim to contribute to the improvement of the living conditions of millions of people living below the poverty line. Given that India is a federal country, the central government needs to coordinate policy guidelines with the states. The public consultation process that renders at best, a common vision of the future course of scientific issues for economic and social development, is close to what in the EU is called joint programming. In terms of Critical Mass orientation there is a strong tendency towards **Excellence** and in trying to meet **Socio-technical challenges.**

Regarding **China,** it seems obvious that innovation policies are first and foremost geared towards economic growth. The current rapid growth performance in the last decade is primarily associated with low- and medium-tech export-oriented industrialization. The policy rationale is focused on domestic R&D and as a result, China faces a rapid technology catch-up process. In this case, Critical Mass becomes a determinant that is necessary to advance catch-up in the technology cycle. Coordinated research by the Chinese government concentrates on making resources available for mission- (technology) and excellence-orientated projects. Some of these technology fields generate a powerful impact on the next generation of technology such as bio-technology, advanced materials and space technology for example. Excellence based policy depends mostly on concepts of high technology parks (HTPs) and massively support the financial endowment of public research institutions. In conclusion, the role of Chinese funding schemes in this framework is somewhat unclear and hard to define. In a rather tentative manner, it could be said that the most likely types of Critical Mass that apply to the Chinese case would be **Excellence** and **Securing competencies/ prospective.** However, there are also a number of indications that other Critical Mass objectives, such as **national/societal challenges** (sending a Chinese national to the moon) are also addressed**.**

Table 7.6 Comparison of objectives related to Critical Mass in the US and BRIC

Country	Socio-technological challenge	Scientific challenge	Securing competence / defensive	Securing competence / prospective	Excellence	Self-sustained dynamics
US	x	x	x	(x)	x	(x)
Brazil	x	(x)		x		x
Russia	x	x		x	(x)	
India	x	(x)		(x)	x	
China	x	(x)		x	x	

Overall, table 7.6 gives a rough overview of the research and innovation policies reviewed in this chapter. It lists the objectives that have been identified in this study as being relevant for the European Research Area (ERA) and which presumably can best (or only) be achieved by pooling a Critical Mass of resources. In the country comparison summarized in this chapter we have compared which of these ERA objectives is also (most) relevant for Research and Innovation policies in the US and BRIC countries. We have looked at the policies and programmes in these countries that are executed at the federal level in general, but we have put a particular focus on those initiatives that try to coordinate or pool a set of individual approaches.

We find that despite the decentralised character of the US political system, there are a number of policies and measures at federal level that more or less address the whole set of objectives. Those objectives related to new or research fields or small and unconnected communities however, seem to be less important compared to addressing challenges and building up or defending excellence. The BRIC countries show a different picture, for the reasons of technological and economic catch-up processes discussed throughout this chapter and their approaches are more focused. In all cases, these approaches include socio-economic objectives to which R&D needs to contribute. In Brazil and China, policy coordination also focuses on empowering, i.e. to build up self-sustaining research communities and competencies in certain fields, but also, sometimes, at inferior technological levels. Excellent, high-tech "islands" in India or China are also addressed by national policies. The case of Russia is paradigmatic for a centralized system of research funding which puts it line with China.

This comparison – although limited to desk research – could give an illustration of the role the notion of Critical Mass plays outside the EU. Even if rarely mentioned explicitly and never defined, Critical Mass, and in particular the objectives that can be addressed by pooling a Critical Mass of resources are a relevant issue everywhere. This kind of research is limited, as it cannot systematically assess how well these countries perform in pooling Critical Mass. In the analyses in another part of the project, we approached this by analysing the patent and publication output not only of European institutions, but also of institutions located in the US and the BRIC countries. This kind of analysis cannot causally link the observed output to certain policy measures, but it can illustrate the strengths of the countries and regions in different selected disciplines, i.e. it can show the level of excellence achieved by different research communities in worldwide comparison.

8 Policy Implications and Recommendations

In this chapter, we outline the policy implications and recommendations based on the key findings and achievements of this study. They have been discussed and validated by experts in a workshop, and have been related to the outcome of a parallel study on scale and scope - the ERASCOPE project.[47] Our recommendations mainly address possible actions by the European Commission that will, of course, often need the support of national governments.

In the ongoing debate about the new policy direction laid down in the "Common Strategic Framework for Research and Innovation" (EC 2011), which aims at bringing all R&D and Innovation activities under one umbrella, the results of this study could create an impact at different levels, i.e. that of rationalizing the ERA, and the operational level of programme implementation and monitoring.

This study was not intended to evaluate the ERA-NET scheme in general, but to illustrate that aspect of Critical Mass and to explore ways of measurement. Any results regarding the achievement or non-achievement of Critical Mass by ERA-NETs should not therefore be used as a basis for policy decisions on the scheme as a whole or on individual ERA-NETs.

The following recommendations are presented largely on an evidence-based reasoning. However, owing to the explorative character of the study, there are some conceptual achievements of the study that have policy relevance and that are therefore included in this chapter.

8.1 Policy implications and recommendations related to policy objectives linked to Critical Mass

I. Critical Mass is a central means to reach policy objectives associated with the European Research Area

This is the starting point of the whole analysis. The Critical Mass concept is a necessary "part of the equation" which transforms inputs (resources) into outputs, while giving a meaning in terms of objectives: a Critical Mass of resources (i.e. above a certain threshold) is required to reach a specific objective that from a policy perspective makes sense. This study cannot come up with clear threshold values, but with hunches about the nature (and combination) of resources necessary to reach certain objectives.

The analytical consequence of the study however, is that in the context of the European Research Area, Critical Mass is required to reach a series of techno-scientific objectives that are logical steps

[47] ERASCOPE final report (2010), Nicholas Vonortas, Wolfgang Polt, Robbert Fisher, Yiannis Spanos, Michael Dinges, Babis Ipektsidis, Maria Pateraki

towards the more general completion of the higher policy objectives of the EC research and innovation policy, especially as they are/will be reformulated in the Innovation Union flagship initiative and the associated Common Strategic Framework Horizon 2020 - the Framework Programme for Research and Innovation (the flagship initiative contributing in turn to the accomplishment of the overall European Union strategy - Europe 2020 strategy). European Research Area and Critical Mass go hand in hand, to the extent that favouring a ERA makes it possible to "create Critical Masses and networks of research effort in strategic areas and to overcome fragmentation and duplication on the funding side via the selective pooling of resources in key areas" (A rationale for Action, EC staff working document 6.10.2010 SEC(2010) 1161 final, accompanying document to Europe 2020 Flagship Initiative Innovation Union COM(2010) 546).

However, it seems important to us that overcoming fragmentation or lack of coordination in the ERA cannot serve as stand-alone policy rationales, as fragmentation is not negative as such, as long as it implies healthy competition among different national approaches that would be able to reach Critical Mass on their own and are, therefore, more than able to address the policy objectives at stake.

Correspondingly, the type of Critical Mass, in relation to the type of Critical Mass objective, varies from one situation to the other, and therefore the way Critical Mass contributes to the achievement of policy objectives varies from one situation to the other. In some contexts, reaching Critical Mass requires pooling a many different resources from a many different geographical origins, in other contexts it is mainly about identifying and selecting a few relevant resources, or coordinating resources that are already pooled in different places. In all cases however, a European Research Area is required in order to facilitate such pooling, identification, selection and coordination processes.

II. Reference to the Critical Mass concept in EU policy should always be accompanied with a link to Policy Objectives, as different Policy Objectives imply different types of Critical Mass

Our main idea is that Critical Mass should be seen as being driven by policy objectives, i.e. that it is a central means to achieve research policy objectives. Our definition is not restricted to recalling an input driven view on research policy (i.e. a mere concentration on pooling funding or bringing together excellent researchers), but clearly includes the output viewpoint too.

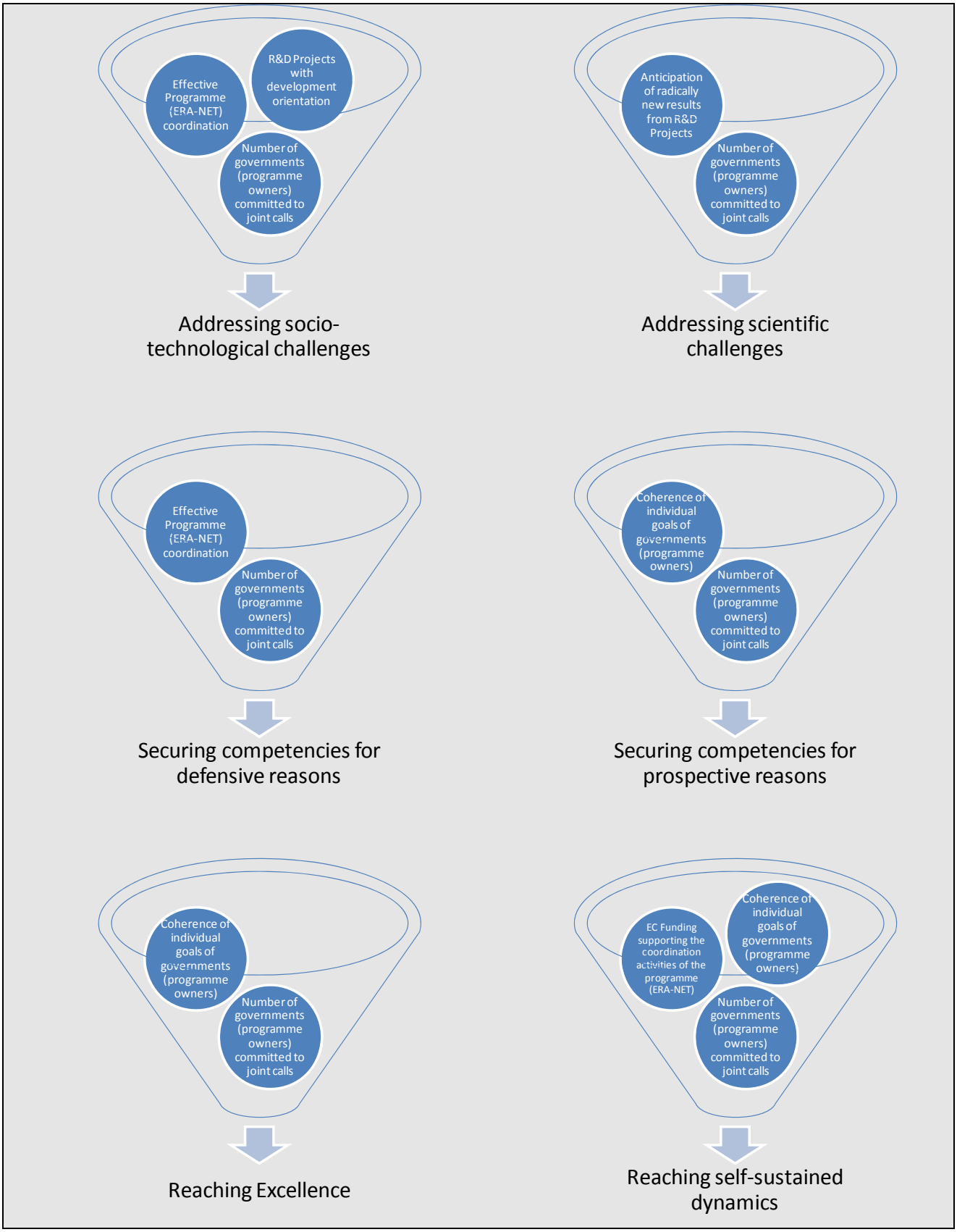
On the one hand, this refers to current developments in Research and Innovation policy, where a turn towards a mission-orientation can be observe – that is a strategic focus in addressing "grand societal challenges". The set of policy objectives we have established in our study refers to the techno/scientific aspects of societal challenges. However, on the other hand, it refers to a different level, and addresses not (only) the level of overarching policy objectives, but the science/technology contents of the fields and therefore includes objectives such as establishing self-sustained dynamics in a particular field, securing certain levels of competencies and reaching excellence.

The notion of Critical Mass can be a powerful idea behind the realizing the potential of the European Research Area. However, any reference to the Critical Mass concept in EU policy documents should always be accompanied by a link to policy objectives. In other words, when targeting the set up of Critical Mass, one should always be precise about the "for doing what", otherwise the rationale is likely rather tautological (e.g. set up Critical Mass to avoid fragmentation).

The results of the empirical analysis support this concept. In the case of ERA-NETs, we find that the achievement of each policy objective and the related Critical Mass type is explained by different profiles or combinations of determinants (figure 8.1 presents those determinants which have shown a statistically significant effect in the quantitative analysis of the ERA-NETs).

Although these results on specific Critical Mass types for different policy objectives can probably not be generalized in all respects as they are based on a lower number of cases (N=49), and although they might be linked to ERA-NET specificities in some respects, they underline the fact that different policy objectives imply different types of Critical Mass, i.e. they require different input profiles.

Figure 8.1 Determinants relevant for achieving Critical Mass objectives



III. Policy objectives of the ERA vary across sectors and time and policies aimed at pooling Critical Masses associated to the objectives need to be based on consensual definitions and analyses of the evolutionary state of sectors

It needs to be emphasized again, that policy objectives are different from one field/sector to the other and that Critical Mass is not therefore intended to reach the same objective in all contexts. This also has consequences on the relevant resources for building a Critical Mass in a specific field and for the determinants and factors that make the resources available.

At the same time, an inter-relation of objectives is expected: they might overlap and more than one policy objective might be relevant in a scientific field or technological sector. Policy objectives might also change or be addressed in sequence as the evolution of a field develops -a potential being first maintained, then developed and used to contribute to solve social needs, and eventually forming a corpus of stabilized knowledge to be preserved.

In submitting precise details about reaching objectives by setting up a Critical Mass, one has to refer to a consensual and reflected definition of the scientific/technical domain or sector at stake. This does not necessarily induce a reference to the same level of granularity of the definition (be it a very narrow or a very broad), but more simply that the perimeter of the domain/sector is documented. Correspondingly, a consensus upon the evolutionary state of the domain/sector and more broadly on some of the contextual factors mentioned in the analysis is also required in order to justify the type of objectives adopted.

Bibliometric and patent analysis requires field definitions in order to select the relevant classes from classification schemes and include the relevant keywords into the search strategies. These field definitions are key to the analysis as they should help to secure that the chosen focus yields a valid picture of the field.

For example, the field of systems biology is characterized by the convergence of life sciences ("classical" experimental - "wet lab" - biology) with information technology & systems science ("dry lab" simulation, modelling). Searching for the publications of the field poses a challenge, as it is an emerging field with contributions from biologists or from ICT research. Consequently, a search strategy using journal classifications (i.e. selecting relevant classes from a set of predefined (sub-) classes of the database employed) would need to include biology and ICT journals, as there is not (yet) a substantial stock of journals publishing systems biological results only. Without any further specification, this would mean that the search result would not only include system biology publications, but also publication from classical biology and from other fields of ICT research. A further specification of the search is possible by employing search terms. These search terms must be chosen in a way that they allow to identify system biological publications, i.e. the

search string must comprise terms, which typically appear in titles, abstracts or keywords of a publication (these three fields of publication databases are often the subject of the search). For systems biology such typical (combination of) terms are e.g. “simulation models of organisms” or “computational models of cell biological phenomena” and similar.

To illustrate this example, applying our definition of systems biology yields a sample of more than 10,000 relevant publications for the field, while a search based on the simple search term “systems biology” yields with roughly 4,300 hits less than a half. A search strategy without any search terms in the publications of computational sciences and several life sciences returns more than 6 million relevant publications.

This example shows that the field definitions, which are key to the analysis, need careful thinking and knowledge about the fields.

8.2 Policy implications and recommendations related to the generalization of the analytical framework

IV. The framework developed in this study for measuring and analyzing Critical Mass has potential to be applied to policy objectives of different R&D programmes

This study has developed an analytical framework for the assessment of Critical Mass in R&D and it has been applied, as an exploratory exercise, to the ERA-NET instrument. However, it can be adapted to many other R&D programmes, as long as their policy objectives are in the scope outlined in this study[48]. Although some elements of the analytical framework (i.e. resources, determinants or contextual factors) would need adaption to other schemes, the framework has some general features:

- Identifying policy objectives related to Critical Mass: In the event that the policy objectives of a R&D programme are rather broad or implicit and/or the programme applies to different research areas, the analytical framework helps determine which policy objectives apply to the individual cases. A set of hypotheses links contextual factors to policy objectives
- For measuring the achievement of Critical Mass the main steps suggested in this study are as follows:

[48] For example, experts of the validation meeting have underlined that the scheme seems suitable for analysing cluster development or the process of “smart specialisation” in European regions.

- First, try to assess, whether the Critical Mass objective has been reached, the basic hypothesis being that if the Critical Mass objective has been reached, it implies by definition that Critical Mass has also been achieved. A series of indicators is available in relation to each type of Critical Mass objective
- Next, check the hypothesis regarding the influence that contextual factors and determinants have on the achievement of Critical Mass and link it with some characteristics of the resources that have been used. A list of several critical factors for the creation of Critical Mass is available

- This approach of measuring achievement covers aspects of effectiveness (i.e. reaching the objectives), but also of efficiency (i.e. relation to resources and the way they are pooled).
- This last step of the analysis, where the achievement is linked to resources makes it possible to draw conclusions about the nature and combination of resources needed to reach Critical Mass for each of the selected policy objectives. In the event the analysis is being applied to a high number of cases, the analysis regarding achievement could also yield reliable results about the relative amounts of resources needed, i.e. about the threshold of resources needed to reach Critical Mass so that a particular policy objective can be addressed. However, our notion of Critical Mass does not take the "one size fits all" approach: the approach is flexible enough to take into account the fact that the amount of resources required to reach Critical Mass varies from one domain/sector to the other and from one objective to the other.

V. The knowledge base established in this study needs to be constantly expanded using data from the empirical analysis of the ERA-NET and other programmes

This study has analysed the definition and measurement of the Critical Mass in public R&D programmes by looking at the specific case of ERA-NETs. The approach to the topic has been kept general throughout the entire project, with a view to it being replicated when studying other public R&D programmes.

The replication of the approach is therefore considered:

- possible, given its wide and general approach
- feasible in cases where gathering data is carried out effectively
- even more fruitful, if data is gathered in a structured way, as proposed in this study

In order for this replication to be possible, the operationalization of the Critical Mass Analytical Framework requires a clear understanding and identification of the various elements, i.e.

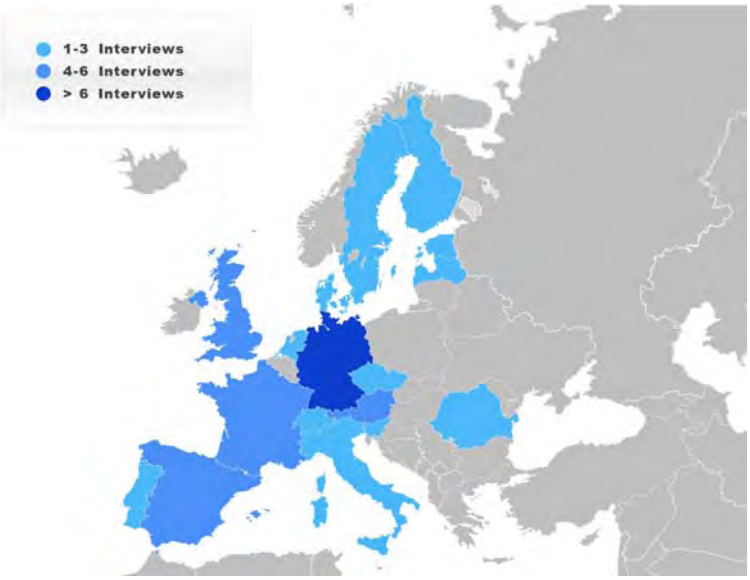
contextual factors, resources, determinants, and finally outputs. A key preliminary step is then to turn the consensual definitions and analyses of the evolutionary state of scientific/ technological domains (see above) into categories and classifications that facilitate the assessment work via different and complementary routes (including internal views from programme stakeholders as well as external views from different existing standardized data sources such as bibliometrics or patent analysis). It is also important, in a second step, to get access to the relevant data especially regarding the resources and their determinants. The more reliable and comprehensive the data, the more possible it will be to get closer to the identification and measurement of the threshold representing Critical Mass.

Given the complexity of joint public R&D programmes in Europe, it is suggested that a two-level strategy, as in the case of this study, be replicated, where:

- an online survey has helped gather a wide dataset on the topic

	Coordinators	Participants	Total
13 Case Study ERA-NETs total	13	55	68
Population (13 ERA-NETs)	13	231	244
Response Rates	100%	24%	28%
Other 39 ERA-NETs	11	69	80
Population (39 ERA-NETs)	39	547	586
Response rates	28%	13%	14%
Total	24	124	148
Population (52 ERA-NETs)	52	778	830
Response rates	46%	16%	18%

- vis-à-vis interviews with a sub-selection of subjects have provided additional information



As proposed in this study, it is suggested that data should continue to be collected periodically, especially so that "panel structure" datasets can be built up. This would lead to the possibility of performing longitudinal empirical analyses, assessing the dynamics occurring in public R&D programmes. A cross-section analysis, in fact, might suffer from contingency affecting its results.

Such continuity in data gathering will enable the structured and homogeneous collection of information from the group of organisations belonging to the R&D programme (i.e. an ERA-NET). On the one hand, each organisation will have a self-assessment opportunity, through a set of defined indicators; on the other hand, this will facilitate the analysis and comparison of the programmes by the European Commission.

Part of the R&D programme funds dedicated to each single participating organisation might be linked to the timely submission of this data to the European Commission, including *ad hoc* article(s) in the funding agreement.

In addition, we suggest that an opportunity be created to develop a **monitoring tool**. The European Commission could ask for the development of a framework (a semi-structured database to be compiled, rather than a format for questionnaires) to be followed by ERA-NET Coordinators and Participants. The existence of such a tool would allow:

- Strict reference to a *tableau de bord* that would ease data collection and control by ERA-NET Coordinators and Participants
- The development of a database fed continuously on the basis of the same structure that would ease the access by the European Commission to data gathered

The knowledge-base, then, might be used not only for evaluating the Critical Mass achievement of past programmes and projects; but also in helping to design of new public R&D programmes and their initial phases of implementation, by providing better advance information about:

- the characteristics of the subjects that the programme should addressed
- the contextual factors that might affect the positive response to the programme, as well as the factors that would hamper this success
- the dynamics that programme participants should generate, and so on.

During the Critical Mass study, some variables that had to be included in the empirical analysis were not obtained due to the non-availability of many programme owners/managers interviewed. For instance, ERA-NET Coordinators had a partial idea of the existence of patents or publications as an output of an ERA-NET. A more specific question on the topic in the Critical Mass online survey was not answered however, as in reference to the number of patents/publications resulting from the ERA-NET, the Coordinators could rarely provide a precise figure.

Among the variables for which only a dichotomy assessment (it is/it is not an output of the ERA-NET) was made during the Critical Mass study – and for which a more detailed data gathering was not possible – we highlight the most important, according to survey response (for each indicator, it is reported the percentage of respondents for which it is important):

number of patent applications to the EPO	22%
number of patent applications to the USPTO	
number of patents granted by the EPO	
number of patents granted by the USPTO	
number of patent citations	9%
number of other IPR (Copyrights, trademarks etc.)	15%
number of scientific publications	57%
number of most cited scientific publications	20%
number of scientific prizes	8%
number of additional researchers (including post-doc, PhD etc.) employed through R&D programmes	46%
number of new research contracts	34%
number of new training programmes	13%
number of spin-off companies generated	11%

Finally, independently from the way data are collected, it has to be noted that a key strategy for good data gathering is to advise programme owners/managers that data will be kept anonymous and confidential. It is suggested therefore that a double dataset be created using the same data – the first to respect the confidentiality issue and provide anonymous information at the disposal of

the public disposal and the second one with full information for internal European Commission use.

VI. The availability of standardized records and keeping track of the Beneficiaries of R&D programmes is necessary for empirical analysis

The Critical Mass study analysed the Critical Mass in public R&D programmes by investigating – through online survey and vis-à-vis interviews – the ERA-NETs. The core strategy has been the data gathering on ERA-NET Coordinators and Participants.

Additional information on the ERA-NETs was expected with regards to the Beneficiaries of ERA-NET projects. It was also expected that there would be preliminary information availability on these players by ERA-NET Coordinators and Participants, at least in terms of a simple list of Beneficiaries per ERA-NET. These expectations proved to be incorrect for two main reasons:

- For some ERA-NETs, the Coordinator/Participants themselves had no structured list of Beneficiaries and no possibility to put together all the sparse information about them
- For other ERA-NETs, the Coordinator/Participants had such a list but could not disclose the information, because of confidentiality

Such constrains led to limited answers to the second type of online survey in the project (named S2 and addressed to Beneficiaries of ERA-NET projects), as shown in section 5.5.2. The project team tried to solve the problem by directly identifying Beneficiaries through desk research, but this has only been feasible in a very few cases.

During the Critical Mass study, some variables of the Analytical Framework were expected to be gathered through the so-called S2 survey, the one addressed to Beneficiaries of ERA-NET projects. We refer mainly to detailed information on the projects in terms of size, the project participants, budget, the geographical location of the Beneficiaries, the type of organisation involved as a Beneficiary and the sector of economic activity and so on.

Beneficiaries that received the invitation to take part in the S2 survey were only around 500, because very few ERA-NET Coordinators and Participants could provide a structured list of their names. The response rate of S2 survey was therefore particularly low and the above-mentioned information could not be gathered.

In parallel, efforts were made to gather this information through desk research, but much of it however, is not in any case, in the public domain. This leads to the need of improving such data collection and availability.

It has therefore been verified that:

- Data on Beneficiaries of ERA-NET projects is missing or difficult to retrieve
- Such data would have been necessary to calculate some indicators in the Critical Mass Analytical Framework
- Main problems for this collection of data have a multifaceted nature, that is:
    - Legal (the data exists but cannot be disclosed for confidentiality issues)
    - Technical (data regarding many players coming from different countries and regarding different programmes, which meant a single dataset is difficult to build)
    - Visibility of data sources (the data exists but it is not easy to understand where it is are kept and who is responsible for it)

As previously noted, data regarding the Beneficiaries of ERA-NET projects, like that regarding the ERA-NETs should be:

- Constantly collected
- Collected in a structured (possibly panel) way
- Continuously transmitted to the European Commission

Finally, it is suggested that the European Commission ask ERA-NET Coordinators/Participants to give higher visibility of the Beneficiaries of ERA-NET projects, albeit perhaps in an indirect manner.

In other words, Beneficiaries of ERA-NET projects could be asked by ERA-NET Coordinators/Participants to inform the public about their link to the ERA-NET. For instance, the fact that the joint call they are a part of was launched by an ERA-NET should be stated in a clearer way (e.g. a clear statement[49] and/or the ERA-NET logo on their websites and publications).

With reference to the empirical focus of this study on ERA-NETs we can only report on the ERA-NET scheme, although we assume that this issue is of general relevance to many types of coordinated action (e.g. Joint Programming).

[49] "This project has been funded in the framework of the ERA-NET X joint call"

8.3 Policy implications and recommendations about key resources based on evidence from ERA-NETs

VII. The achievement of Critical Mass depends on the number of national governments being part of joint activities and on national governments (programme owners) being committed to similar individual goals. Bottom-up approaches appear to be a helpful basis for building common visions, trust and commitment

The empirical results of this study suggest that policy objectives can be better achieved the more national governments (programme owners) are working together: in the case of ERA-NETs we saw, that Critical Mass achievement increases the more partners of an ERA-NET participate in a common activity (mainly joint calls).

The average number of partners involved in ERA-NET calls in this study is 7. This number shows that ERA-NETs work well even if they do not (and cannot) aim to integrate partners from all member states. So, the achievement of critical mass and its related policy objectives is not hampered by the fact, that regularly not all member states can be part of an activity (for different reasons, such as missing scientific, institutional or financial capacities in certain scientific or technological domains or missing political interest in joint European action). Moreover, a high coherence of the individual motivations of ERA-NET partners is a constituent part of the explanation (i.e. statistically significant) for the critical masses related to the following policy objectives: securing competencies in an area for prospective reasons, reaching excellence and reaching self-sustained dynamics.

The following table shows that for these three policy objectives the number of governments (programme owners) involved in joint calls and coherence of individual goals are the most important determinants.

Dependent Variables: Achievement ratios for these policy objectives:	**Addressing Socio-technological challenges**	**Addressing Scientific Challenges**	**Securing competencies for defensive reasons**	**Securing competencies for prospective reasons**	**Reaching excellence**	**Reaching self-sustained dynamics**
Coherent motives of participants				**	**	***
Av. Number of Partners per Call	*	***	***	***	***	**
EC funding for ERA-NET coordination						*
Effective ERA-NET coordination	*		**			
novelty of anticipated results		**				
orientation towards development	***					

***/**/* Positively related to Critical Mass achievement and statistically significant at 1%/5%/10% level.

At a qualitative level, we found in the case study interviews several statements on the importance of the so-called "non R&D" activities in this respect. Non R&D activities such as common strategy building, data sharing or personnel exchange, help according to several interviewees to build trust and commitment among the partners and are therefore an important variable mediating the achievement of Critical Mass and its related objectives, as the following testimony by an interview partner shows:

"The relative success of the ERA-NET is spurred by the somewhat "Olympic spirit" of the participants. It took roughly a year and three workshops until a common vision emerged and it became clearer to the participants what the ERA-Net scheme itself is about. The relationship is shaped by "Trust, Commitment and Understanding". This became somewhat of a lemma and is also often repeated in presentations by ERA-NET representatives. It needed to be acknowledged that the ERA-NET scheme is not for receiving additional funds by the EU but instead is an instrument to spend money together"

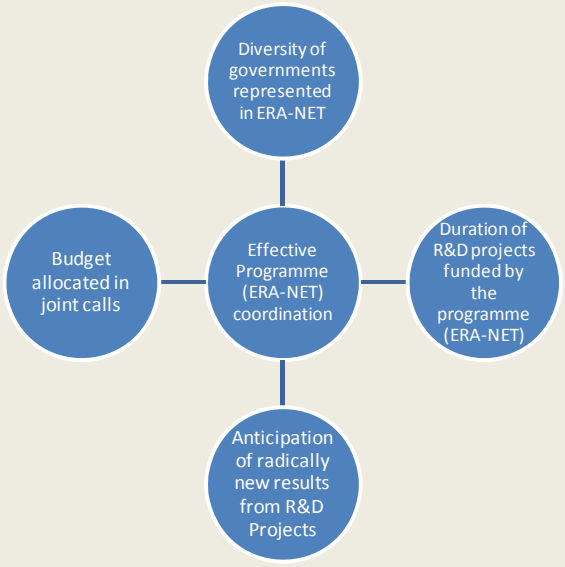
These findings based on evidence from the ERA-NET scheme may allow for some generalizations. As we saw from the empirical analysis that it is not the number of partners (national governments) in the ERA-NET which is decisive for the achievement of Critical Mass and its related objectives, but the number of those who are in fact actively joining forces, it becomes clear that partners need to be committed to the same objectives and consequently, they should also trust each other. This is also supported by the finding that a constituent Critical Mass element for reaching certain policy objectives is an higher coherence of the individual motivation of the partners.

Bottom-up approaches allow those actors, who are committed to the same objective and willing to cooperate, to go ahead with their idea, but also allow others to follow later on. ERA-NETs are an inherently bottom-up concept and there should be more room for such bottom-up activities. Centralized, top-down approaches, although unintended, risk the danger of lacking support of member states.

The ERA-NET scheme allows for a large degree of flexibility. This is very much appreciated by all parties involved, and helps them to pursue the sequence and combination of activities best suited to the research field. In particular the flexibility to perform non R&D activities have proven in this study to be a relevant determinant for creating Critical Mass, as they help to create trust and commitment among the participants. Thus, the ERA-NET scheme is a good example for other schemes which potentially should increase their flexibility and allow more than just R&D activities.

VIII. Effective Coordination is linked to the achievement of Critical Mass and its related policy objectives, and should therefore be given particular support

The empirical analysis of ERA-NETs has shown that the indicator measuring the effectiveness of ERA-NET coordination is correlated to many resource indicators. Effective coordination of an ERA-NET is for example positively linked to a higher diversity of participants being represented in the ERA-NET (from EU-15 big, EU-15 small, EU-12 new, other), or a higher budget allocated by the partners in the joint calls of the ERA-NET. The figure below shows the Determinants/Resources correlated with effective ERA-NET coordination (only statistically significant results are displayed).



Moreover, effective ERA-NET management is a constituent part (i.e. at a statistically significant level) of the profile of determinants that explains achieving Critical Mass related to the following policy objectives: addressing socio-economic challenges and securing competencies for defensive reasons. In the case of achievements with respect to establishing self-sustained dynamics, another aspect of coordination is important. Here, achievements increase in proportion to the amounts of EC funding for ERA-NET coordination.

In the in-depth interviews, the crucial role of the coordinator was also given particular weight. Here, beside his management qualities, it was seen that his own interest in an intensive cooperation at European level is decisive in all activities contributing to the pooling of a Critical Mass of Resources.

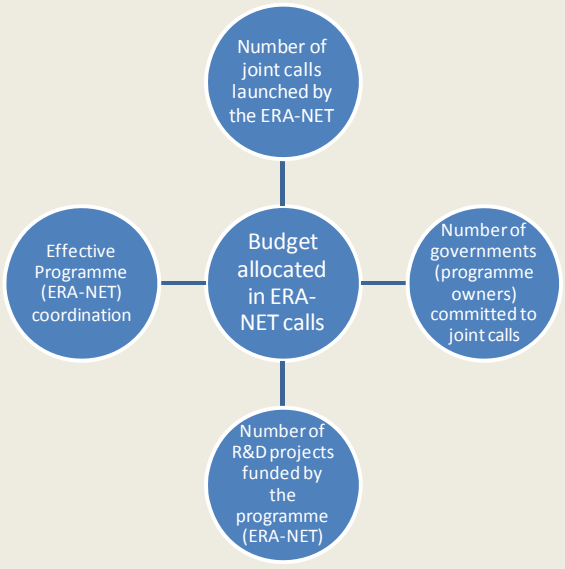
One of the most critical success factors of an ERA-NET seems to be the management qualities of the coordinator. This function is crucial for the "drive" of ongoing activities. Therefore, it is vital that coordination activities receive funding over a longer time period. This applies in particular to the coordination of young, emerging fields. Moreover, the ERA-NETs should be encouraged and supported to work on a solution on how to organise and finance coordination of the network in the long run, at a self-sustaining level, i.e. without EC support.

The observed empirical patterns for ERA-NETs are very plausible and therefore it seems likely that the indirect and direct effects of coordination in achieving Critical Mass and its related policy objectives are not just a pattern specific to ERA-NETs. It is probable that this systematic approach could be also be found in the context of other coordinated programmes.

IX. Promotion of joint funding activities is of importance, in an indirect manner, because it leads to increased opportunities for researchers to collaborate

Funding for R&D activities is perceived to be the key driver in moving towards more competitiveness and growth in a knowledge-based economy. The most remarkable cornerstone of this policy is the "Lisbon goal" to increase R&D expenditure to up to 3% of EU member states' GDP. Consequently, in this study, we have also assumed that budget sizes are a "critical" determinant in reaching all types of policy objectives.

The data collected for the ERA-NETs draw a slightly different picture here: The main budget indicator, which is the overall amount of budget allocated in all calls of the ERA-NET, does not appear to be a constituent element in the profiles of any of the determinants that explain the different types of Critical Mass and related policy objectives. In fact, the total amount of pooled money available for ERA-NET calls is relevant only for achievements addressing socio-technological challenges. Similarly, the average amount of money allocated per call is relevant to achievements in addressing scientific challenges. However, both findings appear to be slightly below a statistically significant level, i.e. the budget size appears to be an additional element but of minor importance. However, budget indicators are correlated to other determinant indicators, which in turn appear to have significant impact on the achievement of Critical Mass and related policy objectives. The overall budget allocated in ERA-NET calls is correlated, for example, to the number of partners actively participating in the calls, an indicator that has shown to be of vital importance in achieving Critical Mass related to all policy objectives.



This suggests an indirect link of budget size to the different types of Critical Mass and policy objectives.

In wider terms, these results suggest that high budgets mainly have an effect when they are allocated by a large number of partners, because only in this case can the budget reach a large target group. In the case of ERA-NETs, a large number of partners in a call means there are increased opportunities for researchers to collaborate. This is supposedly a finding not only applicable to the ERA-NET scheme, but of general relevance.

X. Rather than focussing on the overall sizes and budgets of projects and programmes, more attention could be given to the importance of the (average) funding of individual participants of specific programme actions

Among the crucial factors for Critical Mass, this study does not support assumptions on the role of project size. Critical Mass is often used as a synonym for reaching large scale or large scope, or at least hinting at an increase in size at project or programme level. For many policy makers Critical Mass is understood as being large enough to be visible. Even from an administrative perspective for instance, Critical Mass is seen as increasing scale to reduce administrative burden.

This study however, appears to give evidence that Critical Mass is not related to project size (in terms of partners). Case studies yielded evidence that many ERA-NETs restrict the number of project partners. Critical Mass is undoubtedly visible in small projects as well. Moreover, we found in the quantitative analysis, that for ERA-NETs striving to establish self-sustained dynamics in a scientific field, a small number of beneficiaries per project is an important determinant.

This finding confirms the results of a parallel study (Erascope[50]) that looked into the effects of the scale and scope of projects on the results. The analyses in Erascope showed that the size of the estimated threshold varies considerably across the project performance dimensions such as network outputs, goal achievement, knowledge outputs, technological outputs and the impact of research capacity. In addition, the evidence from the study suggests that it is not necessarily the absolute size but the relative size of a project (partner funding) that might be responsible for Critical Mass effects.

Project scale affects performance in complex ways: mostly, its effects are transmitted through critical intervening variables, such as the how complementary resources, learning conditions, and transaction costs are to each other. When the net effect is negative – which is most of the time – it is because increasing scale lowers the positive effect of resources and learning, and magnifies the negative effect of transaction costs. Conversely, when the net effect is positive – mainly for private enterprises – it is because increasing scale strengthens the positive effect of resources and

[50] ERASCOPE final report (2010), Nicholas Vonortas, Wolfgang Polt, Robbert Fisher, Yiannis Spanos, Michael Dinges, Babis Ipektsidis, Maria Pateraki

learning, and diminishes the negative effect of transaction costs. The underlying explanation of positive or negative net effects must basically be sought in the characteristics of the R&D project.

Bigger is not necessarily better, increasing the scale of (collaborative) R&D projects and programmes without sound knowledge about the 'optimal', or 'most appropriate' size (Critical Mass) should be resisted. Critical Mass should be clearly distinguished from scale and scope and be related to objectives and outcomes. Rather than focussing on overall sizes and budgets of projects and programmes, more attention could be given to the importance of the (average) funding of individual participants of specific programme actions.

9 Conclusions

This Critical Mass Study has been conducted in order to ascertain whether, in selected S&T areas, public R&D programmes in Europe are individually and collectively achieving Critical Mass. This analysis has been performed using a variety of tools, ranging from theoretical speculation (development of a Critical Mass definition and Analytical Framework) to its empirical application to the ERA-NET scheme.

The main conclusions of this Study, to recall what has already been presented in each single chapter, can be summarised as follows:

- In chapter 2, "Methodology of the Study", we have shown how to face the limitation of a missing commonly agreed definition of Critical Mass for public R&D programmes. In order to deal with this shortcoming we employed a multi-dimensional approach that has proven to be effective in studying such a complex topic. Throughout the entire study several activities were carried out: a review of the literature, interviews with experts, the theoretical development of a Critical Mass definition and Analytical Framework, an online survey and interviews involving public R&D programme owners and managers, and comparison with the coordination of R&D programmes in other countries. The results of each activity have been mutually fruitful in gathering new insights on the concept of Critical Mass in public R&D programmes
- In chapter 3, "Critical Mass definition", we presented the new definition of Critical Mass. Through a review of the literature and interviews with experts, we have shown that a Critical Mass concept associated to some sort of economies of scale in intangible assets is only partial. In putting together elements from very different disciplines (physics, biology, business, sociology and economics), an objective-driven definition has been proposed that includes different types of objectives. We propose that Critical Mass should be defined as the "threshold level of resources required during a certain period of time in order to achieve a certain type of objective: to address techno-scientific challenges, and/or to secure a certain level of competences for defensive or prospective reasons, and/or to reach excellence, and/or to reach self-sustained dynamics". These objectives have been considered at a technological/ scientific level and they correspond to significant steps in terms of science and technology development, but at the same time, the notion of Critical Mass in other disciplines has also been taken into account
- In chapter 4, "Critical Mass Analytical Framework", we have outlined the dimensions of Critical Mass (Contextual factors, Determinants, Resources, Objectives) and developed an analytical framework that reflects the interactions and relations between these elements (notably causal relations) that explain the achievement of the given objective. The framework considers pooled resources (human, physical, financial, knowledge and information) to be the actual components of the Critical Mass of research activities. Critical

Mass is achieved when R&D programmes have managed, in a relevant way, to mobilize enough resources to reach the objective. In this framework, we consider a public R&D programme to be one of the means to mobilize resources. However, resources should be pooled under certain conditions, part of which is policy driven. Enabling conditions (cf. contextual factors) are necessary and even "critical" for resources to reach Critical Mass. Though not part of the proposed definition, they are nevertheless important building blocks in our analytical framework as they could explain: i) why a specific objective is assigned to the Critical Mass, and ii) why the determinants are different from one area to the other, or why the same determinants have a different impact on the achievement of Critical Mass. The framework made it possible to develop important hypotheses and to test and verify the link between: how Contextual factors affect Critical Mass Objectives; how Contextual factors affect the Determinants and Resources needed for achieving Critical Mass and how Determinants, Resources and the achievement of Critical Mass are linked together

- In chapter 5, "ERA-NET Case Study rationale", we presented the way the Analytical Framework has been adapted in order to empirically test the achievement of Critical Mass in a specific public R&D programme - the ERA-NET scheme. The ERA-NET scheme was chosen as it presents several features to which the Analytical Framework can be easily applied. We drew up a final list of 13 ERA-NETs based on certain criteria. To gather information on the selected ERA-NETs, we undertook a two-level strategy (quantitative and qualitative analyses) that proved to be very effective. On the one hand, measurement of Critical Mass was possible thanks to respondents' answers to the online questionnaire; on the other hand, in order to complement the survey results, information from interviews helped get a better understanding of relevant issues. The survey strategy directly addressed to public R&D programme owners and managers yielded positive results (100% response rate from coordinators for ERA-NET case studies). Participants that responded to the survey are evenly distributed among bodies that finance research activities, those that manage them and others that are responsible for both financing and managing. It transpired that it is advantageous to complement such information with vis-à-vis interviews with a sub-sample of survey respondents

- In chapter 6, "Critical Mass measurement through ERA-NET Case Study", we have outlined the main results of the empirical analysis. These results show that the Analytical Framework can be fruitfully applied to a specific case, which led, among others, to the following conclusions: all the objectives put forward in the Critical Mass definition were been achieved, albeit at different levels; different profiles or combinations of determinants have to be taken into consideration in explaining the type of Critical Mass achieved; the overall level of Critical Mass achievement in the ERA-NET case is fairly high; ERA-NET Coordinators and Participants have a key role in Critical Mass achievement, for instance in

terms of building trust and commitment or considering existing links among them before the start of the ERA-NET. Moreover, there is a need to bring together as many partners as possible, but they should be committed to the same objective. This and other determinants (such as large call budgets) lead to increased opportunities for transnational research collaboration. In contrast to these positive effects, we found no confirmation that large-scale projects help achieve Critical Mass – a finding that confirms the conclusions findings of the parallel Erascope project on scale and scope in research

- In chapter 7, "The Relevance of Critical Mass and Coordination in international Research Policies and Programmes", we presented a preliminary comparison of the general trends of coordinated research programmes in the US and in the BRIC countries. Although hardly ever mentioned explicitly, the objectives that can be addressed by pooling a Critical Mass of resources are relevant issues in all these countries. A trend in most of the countries analysed, points towards an orientation towards academic excellence. There are considerable differences between the support mechanisms in other countries and the ERA-NET scheme, mainly in terms of different forms of coordination between national and sub-national issues. Similarities with the EU have been outlined, especially in terms of programme orientation, steering of research directions as well as spending priorities
- Finally, in chapter 8, we indicated the main "Policy Implications and Recommendations" with regards to the Critical Mass of public R&D programmes. We put forward, along with others, the following empirically based recommendations:
  - Reference to the Critical Mass concept in EU policy should always be accompanied with a link to Policy Objectives, as different Policy Objectives imply different types of Critical Mass
  - Policy objectives of the ERA vary across sectors and time and policies aimed at pooling Critical Masses associated to the objectives need to be based on consensual definitions and analyses of the evolutionary state of sectors
  - The achievement of Critical Mass depends on the number of national governments being part of joint activities and on national governments (programme owners) being committed to similar individual goals. Bottom-up approaches appear to be a helpful basis for building common visions, trust and commitment
  - Promotion of joint funding activities is of importance, in an indirect manner, because it leads to increased opportunities for researchers to collaborate

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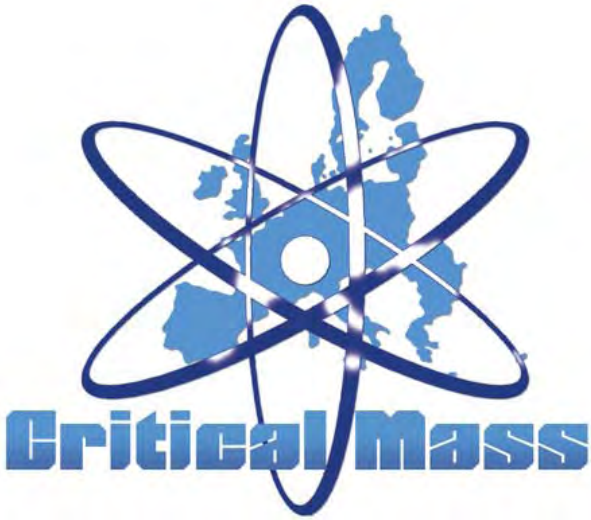
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Study

On the critical mass of public R&D programmes
A potential driver of joint programming



Annex 1

Literature and expert review

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1 Introduction

The literature survey proposed here is intended to cover all of the aspects of the study. It aims at introducing the different concepts and approaches on which the analytical framework will rely on. We will start with the core of the literature survey, which is the part dedicated to the very issue of the Critical Mass concept (1.2). We will then look at the different analytical bricks that are related to the implementation of the concept of Critical Mass in the context of the present study (1.3). Part 1.4 will be more oriented towards key R&D policy concepts that help to understand the policy framework in which the concept of Critical Mass is playing a so important role. Part 1.5 will be devoted to some considerations from the evaluation perspective, since the assessment of the Critical Mass is also part of a more broad family of studies that aim at evaluating the impacts and relevance of the public R&D programmes.

Part 1.6 details the profile of the interviewed experts. The main input provided by these experts can be found in section 3.2 of this report.

2 Existing definitions of Critical Mass: insights from a cross-disciplinary overview

The aim of our research project is to develop a definition of Critical Mass of public R&D programs, to identify the determinants of Critical Mass, and to develop indicators to assess Critical Mass on the basis of a literature overview. The following section outlines existing definitions of Critical Mass issued from a cross-disciplinary review.

There are a lot of articles, books and reports that use the concept of Critical Mass without defining it. It does not seem that there exists a single and widely acknowledged definition of this concept. Historically, the concept of Critical Mass comes from nuclear physics, but rapidly, this concept has been borrowed by others fields and areas.

> *"An atomic pile « goes critical » when chain reaction of nuclear fission becomes self-sustaining; for an atomic pile, or an atomic bomb, there is some minimum amount of fissionable materials that has compacted together to keep the reaction from petering out... The principle of Critical Mass is so simple that it is no wonder that it shows up in epidemiology, fashion, survival and extinction of species, language systems, racial integration, jaywalking, panic behaviour, and political movements."* (Schelling 1978, p.89)

Each area, like nuclear physics, biology, economy, management, social networks, etc., proposes its own definition of the Critical Mass. Several of these definitions can be useful for our study.

2.1 Various Sciences

The concept of Critical Mass has emerged in the area of nuclear physics in the thirties of the twentieth century. It is defined as the smallest amount of fissile material needed for a self-sustained nuclear chain reaction. The Critical Mass of a fissionable material depends upon its nuclear properties (e.g. the nuclear fission cross-section), its density, its shape, its enrichment, its purity, its temperature, and its surroundings.

When a nuclear chain reaction in a mass of fissile material is self-sustaining, the mass is said to be in a *critical* state in which there is no increase or decrease in power, temperature or neutron population. In particular, density is important since it increases the probability for a particle to

"shoot" another particle and then to sustain the chain reaction. When a mass of fissile material does not have ability to sustain a nuclear reaction, the mass is said to be *sub-critical*. A level of neutron activity is proportional to a rate of spontaneous fissions. When there is an increasing rate of fission, the mass is said *super-critical*. In this case, the amount of material can become critical again at an elevated temperature/power level or destroy itself. The mass cannot stay super-critical for a long time; the system tries to reach its equilibrium.

In biology, the Critical Mass is a minimum quantity of bacteria to reach in order to induce a gene expression needed for the well-functioning of the metabolism. In this area, a Critical Mass designates a number, a volume or a quantity that should be reached in order to induce a reaction.

In business area, the Critical Mass is the point at which an organization or project has gained sufficient momentum or the market share is to be either self-sustaining or worth the input of extra investment or resources.[1] In business-language, it means having enough customers or market share to be profitable. A Critical Mass also can be viewed as the minimum size to which is required for a company to enter, sustain or develop in a given market. One talks about "organizational thresholds" allowing to overcome market barriers. These thresholds are related to commercial, technical, financial, human etc factors.

As regards the analysis of R&D activities, in the context of evaluation of the economic impact of public R&D programmes, the Beta has put forward the concept of Critical Mass and tried to propose ways to evaluate it (ASIF team 2002). Broadly speaking, Critical Mass refers to competences / knowledge (accumulated and largely embedded in humans) required to enter or to be sustained in specific activities, and is analyzed at organization level (typically: a firm). For instance, in the evaluation of space programmes: "…, in certain firms space programs support the creation, maintenance or growth of well-structured teams of specialists, scientists, engineers and technicians that constitute what can be called the "Critical Mass" of the firm. The technological potential, which the Critical Mass represents, is a decisive qualification for securing contracts relating to increasingly complex systems in all sectors of the industry" (Bach et al. 1992). In the evaluation of EC/FP Brite-Euram programmes: "[Some effects] tend to describe the impact of the project on the "human capital" of the participant. Each of the participating organizations masters a certain range of competences related to more or less diversified scientific and technological fields, which form what has been called the "Critical Mass" or the "knowledge base" of this organization." (Bach et al. 1995). "A minimal number of employees (scientists, engineers, workers…) required maintaining the level of technological knowledge of a company and to maintain and/or develop its capacity to design more complex products and systems" (Lambert 1991).

2.2 Socio-dynamic area

Critical Mass in social network research is a socio-dynamic describing the scale of a social system at which the system becomes self-sustaining and fuels further growth (Ball 2004). There are various factors influencing the Critical Mass as the size, interrelatedness and level of communication in a society or one of its subcultures. Critical mass may be closer to the majority

[1] http://dictionary.bnet.com/definition/critical+mass.html

consensus in political circles, where the most effective position is more often that held by the majority of people in society. In this sense, small changes in public consensus can bring about swift changes in political consensus, due to the majority-dependent effectiveness of certain ideas as tools of political debate. Thus, the concept of Critical Mass is central to many understandings of collective action. (Ball 2004).

2.2.1 Theory of Critical Mass

We identified several factors influencing the Critical Mass: group size, organizing costs, centrality of the group's participants, individual's interest and resources as money, time, expertise, energy, influence, etc.

Several researchers found that group size is the best predictor of collective action since larger groups have more people and potential resources for action (J. W. Scott & El-Assal 1969). However, theoretically it has also been suggested that it is more difficult to sustain collective action in large groups, since contributions are more likely to go unnoticed or seen as unnecessary (Hardin 1982; F. Scott & Anstine 2002). Oliver and Marwell (1985; Marwell et al. 1988; 1993; 1988) suggested that the effect of group size depends on the costs of providing the collective good. If the costs of the good are fixed or the same regardless of the number of people benefiting from the good, then larger groups are more likely to attain a sufficient subset of interested individuals. This case exists only under conditions of pure non-rivalry between members, thus the participation of all individuals are not necessary. However, when the costs of providing the good rises with the number of people who share it, then large groups are less likely to engage in collective action than smaller ones. Thus, collective action may be supplied by equal participation of all members or through efforts by only small group of individuals.

According to this reasoning, Oliver and Marwell have defined a Critical Mass as **"a small segment of the population that chooses to make big contributions to the collective action while the majority does little or nothing"** (Oliver et al. 1985, p.524). Thus, one key aspect of collective action and the creation of public goods relates to the cost of this creation and the distribution of contributions among the members of the collective. The social network is supported by the Critical Mass of active members, and that members develop strong ties with the community as a whole rather than develop interpersonal relationships. The quality of these members is extremely important, in particular in case of R&D projects (Kitagawa 2009).

> *"Knowledge contribution is significantly related to an individual's tenure in the occupation, expertise, availability of local resources and a desire to enhance one's reputation, and those in the Critical Mass are primarily responsible for creating and sustaining the public good of knowledge."* (Wasko et al. 2009, p.254)

Social interactions between individuals in a network are important predictors of collective action and knowledge exchange. These structural links, in other words, the social ties or network connections are important determinants of helping behaviours and knowledge sharing in organisations (Borgatti & Cross 2003). They reflect an individual's position in the network and can be measured by the type and number of ties linking each individual to others.

Studies in informal organizational structures indicate that central individuals have been perceived to be more innovative (Ibarra 1993), had a higher degree of work reputation and performance (Wasko & Faraj 2005), and interpersonal influence (Friedkin 1982). Individuals forming the Critical Mass of a collective have by definition a higher number of ties and thus have a higher degree of centrality. An individual's network centrality is also positively associated with helping behaviour and performance (Ahuja et al. 2003). Thus, active participants forming the Critical Mass in the

network contribute to sustain this network by participating and creating knowledge (Wasko et al. 2009).

Another stream of research argues that the distribution of individual attributes within the group has important implications for whether or not collective action is successful. It is proposed that the more heterogeneous a group is, in terms of interests and resources, it is more likely that there is a Critical Mass or subset of members who have a high enough level of interests and/or resources to produce the public good (Hardin 1982; Oliver et al. 1985; Olson 1971). However, heterogeneity can also hinder collective action, thus the distribution of heterogeneity of interests and resources is important in terms of achieving collective action (Oliver et al. 1985).

Different levels of individuals' interest affect an individuals' potential degree of contribution. Individuals with higher interest levels are those who tend to gain more from additional contributions to the public good. Interests may include social and/or professional motives (Wasko & Faraj 2000), and Hardin (1982) has argued that individuals with a high interest level are those who lack private alternatives.

Different levels of resources such as knowledge, time, money, facilities, energy and influence are also very important to attain the Critical Mass (Oliver et al. 1985). For a public good to be produced and maintained, it is argued that those forming the Critical Mass are more likely to have access to the required resources. The members of the group differ in terms of their levels of interests and resources, thus they are more likely to contribute to the creation of the public good.

Oliver and Marwell (2001) argue that organizers do not randomly choose from people in their networks, but rather, choose those who will make the largest contributions to the contract. However, "resourceful" individuals with low or moderate interest levels would make partial contributions; this specification is the underlying reason for the generally positive effects we obtain from resource heterogeneity.

2.2.2 Percolation theory

A lot of authors agree that defining Critical Mass is hard and harder still is finding ways to influence its arrival (Westland 2010; Wang 2010; Smith-David 2010; Odlyzko 2010). Often research has been hard pressed to move beyond "perceived Critical Mass" and this is problematic because "perceptions" are not consistent, accurate and useful to provide credible conclusions from behaviour research on social networks. Westland (2010) proposes to involve the percolation theory to define a formal metric for Critical Mass in Internet based social networks.

Percolation theory studies probabilistic models that exhibit a "phase transition" (Hammersley 1957; Broadbent & Hammersley 1957; Hammersley & Morton 1954). Phase changes examples from the physical world would be an egg transforming from liquid to hard boiled, milk curdling and becoming cheese, or rubber vulcanizing. Percolation theory can be explained as follows:

Assume that we would have some porous material and we pour some liquid on top. Hammersley and Morton (1954) modelled, mathematically, this material as a three-dimensional network of n^3 points (or nodes) the connections (or edges) between each two neighbours, which may be open (allowing the liquid through) with probability p, or closed with probability $1-p$. Then for a given p, what is the probability that an open path exists from the top to the bottom? The percolation probability is the critical $p=p_c$ for which there exists an open path from the origin to the exterior of the porous structure. The appearance of an open path for some critical p marks a change from one sort of behaviour to another – e.g., where the soil stops absorbing and the fluid starts dripping.

In case of the social network, assume that we start with some population of individuals (nodes) and each individual will be acquainted with up to z, other members of the social network (Westland 2010).
If the number is *(z-1)*p<1*, then the average number of links decreases at each generation and the probability of finding a continuous acquaintance linkage path between two arbitrarily chosen individuals goes to zero. Only at $p=p_c=1/(z-1)$ such kind of linkage (giant cluster) appears – this conforms to the phase change depiction of the Critical Mass phenomenon. Linkage probabilities $p>=p_c$ assure that network growth is self-sustaining. In social networks, this crossover to Critical Mass means that the giant cluster essentially defines the character of the network. The entire population that might ever be interested in joining the giant cluster perceives this particular social network as the place in cyber-space. For example, to discuss particular topics, meet certain types of people (e.g., young, single, beautiful), build business ties, and so forth.
The appearance of the giant cluster implies a qualitative change in behaviour of the members of the network – what we have called Critical Mass, and for which the phase change interpretation was proposed. The social network never truly defines its topic or crowd until phase change. Thus it is very important for management not to tightly define or lock in the special interest topics, character, operation or membership of a social network until phase change (until $p>=p_c$) (Westland 2010; Smith-David 2010).
To reach Critical Mass and become self-sustaining, social networks not only need to attract new users, but also need to encourage interactions among existing users. More active interactions increase the number of acquaintances a member has in the network. This increased number of acquaintances will reduce the threshold participation level, above which, a giant cluster will emerge and the social network will keep expanding without any intervention from the management (Wang 2010).

2.2.3 Diffusion of innovation and new technology

The field of the diffusion of innovation and new technology also use the concept of Critical Mass (Rogers 2003; Witt 1997; Andreozzi 2004). Diffusion has traditionally been defined as ‘‘the process by which an innovation, that is new idea, is communicated through certain channels over time among the members of a social system’’ (Rogers 2003). In this area, the Critical Mass has been defined as the minimal number of adopters of an interactive innovation for the further rate of adoption to be self-sustaining (Rogers 2003). Williams (1988) indicated that the rate of adoption is slowly diffused in the early stage of diffusion, and that the rate of adoption increases faster after the Critical Mass is reached.

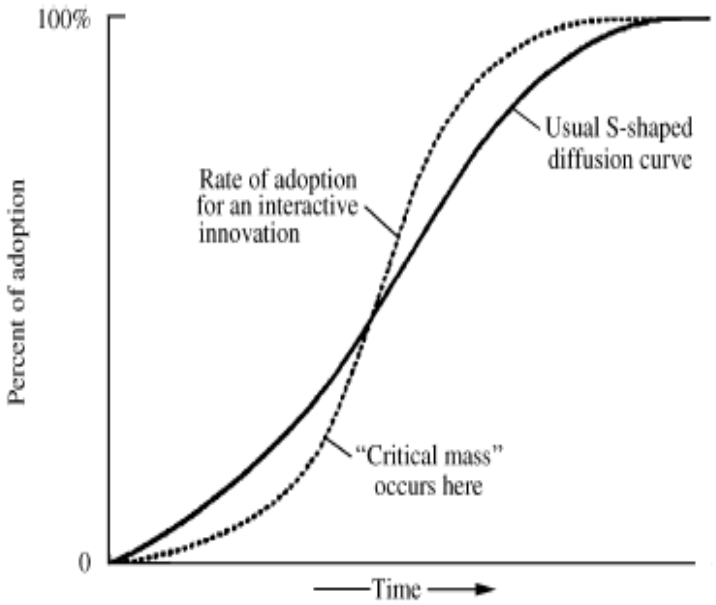


Figure 1 The rate of adoption for innovation (Williams 1988, p.73)

Williams (1988) explained that the reason for the late-take off phenomenon in the diffusion of interactive innovations is due to interactive nature of them. According to his reasoning, an interactive innovation is of little use until a certain number of adopters, that is Critical Mass, are achieved with which prospective adopters wish to communicate. This happens because value of the interactive innovations lies in the connection among adopters. Therefore, the adoption starts slowly and increases fast after reaching the Critical Mass.

It seems very difficult to measure the Critical Mass point in the rate of adoption, since it is often a problem to determine when further diffusion becomes self-sustaining (Lim et al. 2003; Mahler & Rogers 1999). Valente (1996; 1995) has called this the point of Critical Mass *threshold* because of the behaviour change of adopters of interactive innovation. Mahler and Roger (1999) suggest that reaching Critical Mass depends less on the objective number of adopters of an interactive innovation than on the perceived number of other adopters. In case of interactive innovation, the Critical Mass is socially constructed by individuals, based on their communication with others who are relevant in their system.

> *« Each person has, as it were, an individual vision of what constitutes Critical Mass... upon everybody watching while being watched... Critical Mass for the group floats it seems on shifting perceptions of what the group outcome may be. »* (Allen 1988)

2.3 EC Literature

The notion of Critical Mass was widely used in the 2004 Commission Communication on future European research policy. It stated that the Community could encourage companies to invest more in research in Europe through the creation of "centres of excellence" of Critical Mass. The concept of Critical Mass has become even more important in FP7 (Piech 2007).

Generally, the white papers, evaluation reports and others official documents of EC use the concept of Critical Mass without specifying its definition (Piech 2007). In the official documents of European Commission the Critical Mass is mainly defined as bringing together more participants and pooling their resources (EC 2004). This definition is not justified, because of lack of clarity.

"The Commission has not properly defined the concept of 'Critical Mass' and participants have often constructed artificially large consortia perceiving size and composition to be determinant for success, while excellence should be the determining factor." (EC 2004)

European Commission's experts suggest that "Critical Mass" depends on the research's topic, the thematic area, the participants and the potential impact (EC 2004). The 2000 Commission Communication on ERA called for more coherence between measures taken on different policy to attain the Critical Mass in the major areas of progress in knowledge (EC 2000).

Multi-partner projects of European Commission aim at strengthening excellence on a research topic by networking the Critical Mass of resources and expertise (Guy et al. 2004; Guy et al. 2005). This expertise must be networked around a joint programme of activities aimed primarily at creating a progressive and lasting integration of the research activities of the network partners while at the same time advancing knowledge on the topic. The Critical Mass expertise is not necessarily achieved through large concentrations of researchers and technicians in one location, but through virtual networks as well (EC 2003).

It can also be noted that OECD has very recently used the notion of Critical Mass and its supposed link with the capacity of countries to reach excellence in innovation, thanks to attraction of resources to specific locations (pledging for coherence of policy at local/regional, national and international levels) But again, this mention was made without providing any definition of Critical Mass (OECD, 2010).

3 Analytical bricks

In this part, we will introduce some analytical concepts that we think are of the most useful for the study of Critical Mass. The concepts presented here are covering a wide scope of issues, from pure economics issues to analysis of policy or policy evaluation issues.

We will address the following concepts and analytical tools:

- those which are based on to the so-called production function approaches, which provide the theoretical background of concepts such as scales or scope economies;
- those which are derived from a more dynamic approach, which in particular provide the framework for analysing the development of capabilities and changes in network properties;
- those which allows to take into account the different dimension of the resources and of the outputs of research activities, projects, or programmes;
- finally, those which are related to the issue of coordination of resources.

3.1 The production function approach

The production function approach is one of the most standard concepts and tools used in economics. It is a way to formalize the activities of economic agent(s) by taking into account the "inputs" and the "outputs" of the activities. Activities at stake could in theory be of any kind, but the approach was initially designed essentially for physical production essentially. Correspondingly, what transform inputs into output can be considered as a system. Usually, it is under the form of a mathematical function: Output = F(Inputs). A lot of different specifications of this mathematical function have been proposed, in particular the Cobb-Douglas type which is the most often used in econometrics.

Behind its apparent simplicity and obviousness, this approach relies on a lot of assumptions which are not so straightforward, especially when one wants to use the approach in the case of R&D activities as a specific case of production (of knowledge in this case).

First assumptions are that inputs and outputs can be identified, described and measured (see section 2.4 below for more comments on this point). Second the relation between the two must also be formalized and must show a certain degree of stability over time and range of output. Third, most of the time it is assumed that the function is the result of a optimisation process, i.e. the function gives the account of the maximum level of output that can be produced for each quantity/combination of inputs. In other words, economic agents are supposed to exploit their resources at the maximum. Fourth, most of the time outputs are considered as being analytically distinct from the activities (or the system) that produce it (e.g. cars are distinct from the production activities or from the production workshop, patent is distinct from the research activities or from the research team). It means that the production function approach barely takes into account the fact that the system itself can be affected by the carrying out the activities (to the exception of some forms of wear or obsolescence of the system). Those hypotheses raise the problem in the case of production of goods, but are all the more arguable when production of knowledge is at stake.

The concept of production function is basically a concept expressed in physical terms. Associated to the production function is often the cost function. Cost function related the quantity of outputs to the cost of producing it; more precisely, for any level of output, it shows the minimum cost for producing it, given the price of the inputs. Again, it is assumed that the actors are able to optimize the cost of the utilisation of their inputs. However, it is only under certain circumstances that the production function and the cost function are fully the dual and corresponding faces of the same coin: more precisely when the price of the inputs is constant whatever the amount of inputs are used by the producer (is when all inputs are in perfectly-elastic supply to the organisation).

A detailed discussion of economies of scale and scope in research is provided in Vonortas (2008). We briefly come back to some of the issues here and discuss some relations with the one of Critical Mass issue.

3.1.1 Economies of scale

The concept of economies (diseconomies) of scale is often related to the one of increasing (decreasing) returns to scale. The concept of returns to scale is used to describe what happens to output when all inputs are increased together (given a specific technique in place). An increase in all inputs, resulting in a more than proportional increase in output, indicates increasing returns to scale. Increase of output of the same proportion, than inputs equals the constant returns to scale. If the output increases by a smaller proportion than all of the inputs, this denotes decreasing returns to scale. It is important to underline that it is assumed here that all inputs are increasing in the same proportion. If this is not the case, then it is not possible to talk about returns to scale (or the approach would be of a higher degree of mathematical complexity). In research, this hypothesis is far from being easily acceptable.

Two main possible reasons are often put forward for explaining increasing returns to scale, and they are especially important in the case of research activities: specialization and indivisibilities (dimensional effects are also sometimes evoked). Specialization means a finer division of labour as

the research project grows larger, allowing higher productivity of the inputs. Indivisibilities exist when certain inputs are available only in certain minimum size; then larger research scales may use such inputs more efficiently; a typical example is the large physical infrastructure.
Enlarging the research scale may cause some coordination and control complications; this is the basic argument explaining the possible decreasing returns beyond a certain scale.

The concept of Critical Mass is not part of the standard theoretical framework based on the production function approach (Varian, 1992). However, it can be associated to three different issues. The first is this issue of indivisibilities of inputs (see also below). When it is not possible to produce any unit of output if a certain amount of inputs is not available (in research, this is typically the case when specific instrumentation is required to do experiments), then this level of inputs can be considered as critical. In this sense, a Critical Mass of inputs is the minimum amount of inputs allowing to produce at least one unit of output. Secondly, it may happen that the production function exhibit constant (or even decreasing) returns over a range of inputs, and then beyond a certain level of output, increasing returns are obtained. This level of input can also be considered as a Critical Mass of input. Third, more broadly, in theory, the very definition of production function could lead to another interpretation of Critical Mass of inputs; since it shows the maximum amount of output (let's call it Ya) than can be produced with a given amount of inputs (let's call it Xa), Ya cannot be produced with less inputs than Xa, but can be produced with more inputs than Xa. Then Xa is the minimum amount of inputs than is required to produced Ya, ie it can be seen as a Critical Mass of inputs required to produced Ya. In other words, the production function should be seen as a function showing the Critical Mass of inputs required for any level of outputs.

As stated before, economies of scale is another concept. It is measured in terms of properties of the cost function. When average cost is decreasing (respectively increasing) with the research scale, we find economies (respectively diseconomies) of scale. Introducing cost leads to other issues as the possibility to get input at discounted price because of the bargaining power with suppliers. For instance this would be the possibility to have access to input for free, in an environment like clusters (i.e. benefiting from externalities from the environment).
One often considers that the production is at its optimum when the producer reaches the quantity of output corresponding to the minimum average cost (i.e. the lowest point of the average cost function). When the average cost function is decreasing to a certain point and then remains stable for a superior range of output, it is often argued that the lowest quantity at which the minimum average cost is obtained represent some forms of critical point (minimum efficient scale). Under the conditions of duality mentioned above, the minimum efficient scale could correspond to the turning point of the production function, ie the quantity of inputs below which the function exhibits increasing returns (corresponding to economies of scale) and beyond which it exhibits constant returns or even decreasing returns (corresponding to deseconomies of scale). However, this minimum efficient scale is optimum in terms of cost only, but there is no reason for a priori believing that it is the optimum point in terms of level of output. This optimality of the level of production in terms of cost should not be confused with a notion of Critical Mass considered in physical terms.

3.1.2 Economies of scope

Economies of scope happen when different outputs are less costly to obtain when different processes that lead to these outputs are carried out jointly, as opposed to when they are carried out separately (Teece, 1980, 1982; Panzar & Willig, 1981; Baumol, 1977). Economies of scope in research may result in situations where several research projects are carried out involving the same inputs, such as the same management and S&T knowledge, skills and capital equipment, thus allowing for cross-fertilization and productive exchange. The basic idea here is that knowledge (as an input to the research activity) is at least partly a non-rival resource that is not destroyed when using it. It can be used in parallel or successively in different research activities. Increasing complexity of the research endeavour, multi-disciplinary team, complementarity of knowledge are also key in this respect.

Again, economies of scope is a concept related to cost and not directly to physical amounts. It is thus related to the optimisation of cost and not necessarily to the nature or quantity of the output. In addition, economies of scope is relevant only when different outputs are produced. In this context, Critical Mass may be considered when a given input should be available in a minimum amount for being used for producing different outputs. Again, this may be the case when this input is indivisible.

It should be noted that theoretical literature has combined the scale and scope analysis, showing that some scale effects can be obtained on the production of one output thanks to scope effects. Whereas, producing the same output alone would have not induced such scale effects.

Vonortas (2008) discusses a lot of limitations of the concept of economies of scale and scope too strictly "transferred" from the classical production to the field of research activities (i.e. the production of knowledge). The range is from the advantage on the market provided by differentiation of research, even at a lower research scale (sub-optimal in terms of cost), the critics of some form of the linearity of the cost function, the state of development of the science and technology, etc.

3.1.3 Indivisibilities and complementarity in R&D

It is important to analyse the relation between the notion of Critical Mass (although not completely defined) and the key notion of indivisibilities and of the complementarity that are at the heart of the notion of economies of scale and scope in R&D.

As previously stated, indivisibilities is one of the reasons explaining economies of scale, and supposedly Critical Mass.

Often research projects need a critical minimum amount of resources to make it possible. Again infrastructure is one example. However, it does not necessarily mean that a Critical Mass has been reached when the indivisible resource is at disposal. One could then distinguish between a threshold of the possibility of conducting research and the Critical Mass of research. Innovation is also linked to high indivisibilities, in the sense that the cost to introduce a novelty may be a constant cost, and thus the more "copies" produced afterwards the less the average cost. Spreading of fixed costs of R&D over more R&D output, increases the incentive to invest in R&D (expansion of the R&D activities due to the economies of scale in this activity). Once a Critical Mass has been achieved, actors can have the motivation to reorganise the R&D process by centralising knowledge, reorganising R&D teams and specialising in R&D tasks, while setting up parallel projects. These changes should lead to higher R&D output. They are measured through

the speed of developing knowledge, introducing new products and processes, and to higher R&D performance. They also include more productive R&D personnel and R&D management.

Combining different R&D programs within the same organisation can create economies of scope in R&D, leveraging R&D investments across different R&D projects. Economies of scope in R&D will tend to broaden the mission of the organisation's R&D process. People from different disciplines or different organizations would learn from one another and the combination of their knowledge might create a new idea towards which their research would be re-targeted. We call this the *complementarity factor* of research collaboration. In fact, such complementarity has been raised most often as the major motivation of joint R&D. Furthermore, complementarity was the major reason for increased research efficiency.
Synergies and complementarity are not equivalent to economies of scope. Economies of scope are measured across different outputs, while here we consider the input level. Once Critical Mass is achieved, different R&D inputs can be combined and potentially realise new outputs. R&D outputs could achieve efficiencies that could not be achieved previously or only at prohibitive costs. Combining resources and capabilities might create knowledge and capabilities that did not exist before. After Critical Mass is achieved, projects can be feasible that were not feasible before. This would happen because of the transfer and fusion of existing knowledge and technology, which reduces the cost of operation across R&D projects and increases the incentive to invest in R&D. Critical Mass can, therefore, affect the R&D organisation through the transfer of knowledge, the (re)organisation of joint teams, specialisation of R&D tasks and the sharing of R&D resources. Critical Mass allows a broader portfolio of technologies resulting in increased R&D output and improves R&D performance. Critical Mass will typically broaden the scope of R&D that is performed.

3.1.4 Spillovers and externalities

Spillovers correspond to externalities of economic activity upon actors who are not directly involved in it. They represent costs (negative externalities) or benefits (positive externalities) not transmitted by any price mechanisms. In R&D activities, the presence of spillovers underlines the inability of firms to fully appropriate the gains resulting from the commercialization of their research. The economic literature usually distinguished between two types of spillovers:

- The involuntary spillovers which correspond to a leakage of information from one company to another and which is not controlled by the emitting firm;
- The voluntary spillovers which could resemble to a voluntary exchange of technological or scientific information between firms.

The level of spillovers is influenced by a certain number of factors: industry, country, type of research and product, and the nature of contract signed between the agents. For instance, intra-industry or intra-country spillovers are high in industries or countries with high technological potentialities, such as automotive industry or ICT (Jaffe, 1986). According to Berstein (1988), inter-industry spillovers seem to be less important than intra-industry ones, because products and processes of production differ more between industries than within. The environment in which companies act is important. For instance, Porter (1990) states that knowledge spillovers stimulate growth in specialized geographically concentrated industries. Porter's externalities are maximized in cities or clusters characterized by highly specialized competences. Like Porter, Marshall-Arrow-Romer think that the proximity of firms in the same industry affects the way the knowledge flows from one firm to another and facilitate innovation. For instance; many semiconductor firms

intentionally localized their research activities in the Silicon Valley to take advantages of existing spillovers. The Jacobs spillover concept differ from the other two in that it considers the way the knowledge flow between companies close to each other, but acting in different sectors or industry.

Cooperative R&D agreements are often considered as a means to internalize involuntary spillovers and to allow for a higher level of R&D expenditure as compared to a non-cooperative situation (D'Aspremont and Jacquemin, 1988). However, when firm decide to cooperate in order to achieve a common R&D project, they will exchange voluntarily scientific and technological information, thus create a voluntary spillover which will benefit only to the members of the consortium. These spillovers are usually distinct from the involuntary ones, external to the consortium. The companies will thus partly benefit from the external environment and from the research done with the partners.

The achievement of Critical Mass will most probably be influenced by the environment (industry, country, geographical conditions) and the organizational form (cooperation, in-house) in which the research takes places. The achievement of Critical Mass and thus innovation will be facilitated in environment with important knowledge spillover effects, such as cooperative agreements in sectors with high technological potentialities.

The concepts belonging to the production function paradigm have strong but not really explicit and well established links with the notion of Critical Mass; Critical Mass can be related to various aspects of these concepts. However, a lot of basic hypothesis on which these approaches are relying can be put in question when dealing with research activities. In addition, cost oriented approach and/or look for optimality and efficiency are most of the time associated to these approaches, and are not easily compatible with the notion of Critical Mass. The existence of spillovers (by the way not restricted to the production function paradigm) may favour the interactions between actors and thus increase their productivity broadly speaking.

3.2 Dynamic approaches

3.2.1 Increasing return in networks

In a R&D production processes, beyond a certain level of resources and knowledge (indivisibility or complementarity of resources) the pooling of resources does not lead to any production: there is no Critical Mass. Above a certain level, the production of R&D results starts. The underlying resource/knowledge (large equipment, infrastructure, funding, common laboratory, number of innovative researchers working together, research-supporting assets) must exist on a certain minimum scale before any production can take place at all and this necessary minimum is independent of the rate of production. A familiar example of such indivisibility would be a railway, which must be constructed in its entirety before any trains can use it. It also must be constructed whether it is used by one train per day or fifty. The latter point also means that there are scale economies in the use of indivisible capital goods and this applies to knowledge. Indivisibility, particularly in presence of uncertainty, leads to straightforward under-provision of knowledge and suggest that the public sector should either produce knowledge directly, or provide subsidies to knowledge-producing institutions.

Sometimes there are parts of the research process that cannot easily be divided. This structural characteristic of innovation leads to the need to use compact amounts of money, rather than atomistic funding structures. Above the threshold K_0, a project/program can enjoy a virtuous cycle in which K allows innovation, and innovation creates further K. Under conditions of indivisibility and dynamically increasing returns, it is critical to reach a threshold size. Under the threshold, the output effect of performing R&D is not yet big enough for R&D expenditures to be completely recovered with the profits derived from the investment. There is a minimum amount of investment below which R&D activities have no effect. A project that grows beyond this threshold is likely to enjoy a positive feedback cycle in which K and innovation sustain each other. The innovation process becomes cumulative and self-reinforcing. According to Arthur (1989) and David (1985), this dynamic is caused by vertical and horizontal network externalities, technological complementarities, localized learning processes and scale economies. The project or the program becomes an attractor.

Critical Mass may be required to cover R&D costs, which might not be possible when initial R&D costs are too high, given the indivisibility of the initial R&D investment. Indivisibilities may be related to both inputs and outputs.

"There are substantial indivisibilities in R&D at both the micro and macro levels. At the level of individual projects, a wide range of technological areas require the commitment of relatively large amounts of R&D in order to make these projects at all feasible (in other words, the minimum efficient scale of projects in such areas is large). At the economy-wide level (program), the conduct of R&D requires a vast array of supporting infrastructure and services, the availability of adequate manpower (not only scientists and engineers but also supporting personnel of various sorts), and of financial institutions and markets. All of these will come into being only if enough R&D is being carried out to justify the emergence of the required infrastructure, venture capital institutions, etc. Moreover, the ability of firms conducting R&D to capture the spillovers generated by others in the same region or country, as well depends on the existence of a sufficiently large nearby R&D sector" (Trajtenberg, 2002).

3.2.2 Dynamic capabilities

Teece et al. (1997) define dynamic capabilities as ‘the ability to integrate, build, and reconfigure internal and external competencies to address rapidly-changing environments’. This concept has been developed to answer a shortcoming of the resource-based view of the firm. The latter approach ignores the factors surrounding resources in explaining the performance of firms. The way resources are developed, integrated within the firms and released, is not well-studied in this stream of literature. The dynamic capabilities framework supposes that to react to fast changing market and environment, firms should react quickly and be innovative. Dynamic resources help firms to adjust their resources and maintain, in a sustainable way, their competitive advantages. In other words if the choice of resources is an important decision, the ability to develop and renew them is even more crucial in a dynamic approach. At least three processes are important for firms to be sustainable:

- To be innovative and creative, firms and their employees need appropriate learning capabilities.
- A firms performance is related to its ability to coordinate and integrate strategic assets

- Strategic assets have to be transformed and reconfigured: the firm has to undergo the necessary internal and external transformations to cope with the changing environment.

3.2.3 Learning and absorptive capacity

The dynamic capability approach leads us to suppose that not only the type of resources involved in an innovation process is important, but the way they are combined, developed and renewed is critical in a dynamic perspective. The ability to create resources is intrinsically related to learning abilities and the absorptive capacity of firms.

The notion of absorptive capacity (ACAP) is important because it provides a way to specifically conceptualize the learning mechanisms that underlie the processes of exploration and exploitation. Building on the work of Cohen and Levinthal (1990), Zahra and George (2002), defined ACAP as the set of capabilities that relate with the acquisition, assimilation, transformation, and exploitation of knowledge to finally produce innovative marketable results. While the concept of ACAP was originally formulated to explain knowledge creation and exploitation at the firm level, it has recently been extended to capture inter-firm relations. For example, Lane et al., (2001) utilized the notion of ACAP at the alliance level and found that commercialization of research results was strongly related with the absorptive capacity of the alliance, which in turn, was influenced by such factors as strategy and formal goals, trust and cultural compatibility between partners, and relatedness of partners' technological and market areas.

Van den Bosch *et al.* (2003) proposed two major groups of determinants of the absorptive capacity of a consortium:

- the various a priori related knowledge domains, problem solving skills, prior learning experience and learning skills, and a shared language
- the consortium aspects, such as structure of communication, the character and distribution of expertise and knowledge within the collaboration.

The ACAP is rarely measured directly but rather built with elements related to the pool of resources or the projects characteristics.

This part on dynamic approaches provides important elements to take into account in the analysis of Critical Mass. In situations characterized by indivisibilities in R&D and dynamically increasing returns, it is critical to reach a threshold size of resources (adequate manpower, money, infrastructures, services etc) to create innovation. The Critical Mass will allow for a virtuous circle in which innovation becomes cumulative and self-enforcing. This dynamic due to network externalities, technological complementarities and localized learning will attract new actors in the specific innovation field. This dynamic strongly depends on the firms' absorptive capacities and learning abilities that will help them to capture knowledge spillovers and to create new knowledge.

3.3 Resources

3.3.1 Project / programme size and budget

Depending on the level of analysis, the resources can be analyzed at project or programme level. When the project level is considered, the resources are those directly of the participants of the projects. Then complementarity, synergy, cognitive and cultural distance etc, have to take into account the fact that the resources are actually working together. When the programme level is considered, the resources considered are split between different projects. Then even if the resources are of the same type, their relations should not be considered in the same way.

3.3.2 Funds, stocks and flows

When one tends to measure them, resources are often considered either as flows (number of unit per time, even if time is not always explicit) or as stock (amount of unit that are at disposal). The relation between flow and stock is that the stock is diminishing when it is used. The flow is the measure of the decreasing level of the stock. Alternatively, a flow can increase the quantity of stock. This very basic and standard view is largely to be put in question when dealing with other sort of resources, in particular knowledge or competences. Related to their (partly) non-rival characteristics, the level of these specific resources are not decreasing when one uses them; the possibility (apart from the question of the access to it) to use them is only related to their utility that decreases only when they become obsolete. In this sense, they are clearly different from human resources when considered in the standard way (labour hours) or from physical capital. The concept of "fund" (Georgescu-Roegen, 1971) can better take into account the characteristics of these resources: it is indivisible, time is needed to form it and to destroy it, and (in the case of human embodied knowledge) there is a need of using it and sometimes to update it for maintaining its capacity to produce something. This analysis may greatly enrich the understanding of the Critical Mass and the way to create and maintain it. It also strongly played against a much too narrow application of the standard tools related to the production function to the research activities.

3.3.3 Pool of resources

There are many typologies of resources. According to the resource-based view (Barney, 1991), resources can be classified into three main categories: physical, human, and organisational capital (e.g. formal reporting structures, planning, control mechanisms, etc.). Hyder and Ghauri (2000) propose a five categories classification of resources that partners bring in an R&D consortium:

- **Input** resources refer to those that can be procured through market mechanisms,
- **Capital** refers to the physical resources invested by the partners such as buildings, transportation means etc.
- **Human resources** devoted to the project are a crucial factor for project performance. According to the Frascati Manual (OECD 2002), two approaches may be used to classify R&D personnel: the most commonly used is by occupation, the other is by level of formal qualification. By type of occupation, the OECD distinguishes between different types of R&D personnel, such as *Researchers* (professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned), *Technicians and equivalent staff (who* participate in R&D by performing scientific and technical tasks involving the application of concepts and

operational methods, normally under the supervision of researchers), and *Other supporting staff* (supporting the two preceding classes). A classification by level of formal qualification is provided by joint OECD/UNO/Eurostat classification (ISCED Classification of education level)

- **Technology resources** refer to partner's technological know-how and skills in the areas of product design and architecture, production and process techniques, and managerial systems used to manufacture particular products. Technological resources may be taken into account by considering prior patents and innovations of the consortium in the relevant field of work.
- **Market resources** concern market power, market knowledge, access to distribution channels, etc. .

Research has consistently shown that the degree to which partners collaborate effectively is significantly determined by the extent to which they commit resources to the project (Varadarajan and Cunningham, 1995; Tsang, 1998).

An important point here is that some resources can hardly be measured directly, and that proxy resources have to be used in many instances.

3.4 Outputs

There are two points here should be stressed. First, there is a long list of possible output of the research activities. In particular, recent research has greatly improved the scope and the availability of the Science and Technology output indicators. One has to distinguish two issues here: the very possibility of measuring output of research, and the existence of objective and widely acknowledged source of information about the output. Publications and patents are the most commonly used, despite their limitations for measuring the creation of knowledge. Secondly, following the extensive meta-surveys of evaluation methods and studies (Georghiou et al. 2002; Fahrenkrog et al. 2002), the evaluator often distinguished the output of the research, the impact of the use and the diffusion of the output across the research system or across the society as a whole. Sometimes, an intermediate level is also considered (the "outcome"). A key point here is that a conceptual and interpretative framework is required to identify, understand and possibly measure the dynamic process that make the output lead to an impact.

3.5 Coordination and control

3.5.1 Transaction costs

Transaction cost economics is probably one of the most cited approaches explaining the comparative advantages of alliances as governance modes. It insists on a static efficiency criterion: the minimization of coordination costs. Williamson (1979) provides an interesting interpretation of Macneil's (1974) typology concerning three contract law doctrines. The first law doctrine is the classical contract law (cf. contingent claim contracting), based on complete presentation in formal documents and well adapted to anonymous transactions, weak asset specificity and a stable environment. The second law doctrine is the neo-classical contract law (cf. incomplete long-term contracting), based on trilateral governance (arbitration) as a means to resolve disputes among parties, while simultaneously preserving the continuity and flexibility of the relationship. It is supposed to be efficient for occasional transactions and for medium to high levels of asset

specificity. Finally, the third doctrine is the relational contract law, which relies on norms and past behaviours to provide efficient adaptation mechanisms in the case of idiosyncratic assets and very complex, uncertain and recurrent transactions.

3.5.2 Trust

Behind this typology lies a dilemma due to the necessity to cope simultaneously with opportunism and uncertainty. Specifying written contractual terms helps to reduce the probability of opportunistic action but diminishes adaptation abilities. Whereas informal mechanisms preserve flexibility, while possibly opening the door to "bad behaviours". When applied to our issue of internal coordination of R&D alliances, this dilemma can be developed as follows:

- On the one hand the coordination and division of labour can be obtained through formal, detailed contractual terms and safeguards specified through a costly negotiation process. Unfortunately, this formal specification of the allocation of the tasks, obligations, and outcomes for each party can be very inflexible and thus inefficient in a quickly changing context. In particular, an overly detailed description of inter-partner division of labour can impede and block exploratory learning.
- On the other hand, relational or psycho-sociological contracts based on routines, trust and informal coordination processes make the filling of the "contractual gaps" less necessary. In this sense they are better able to preserve the flexibility of the tasks to be achieved. The problem is that they need a favourable climate and time to emerge since they are built on past behaviour.

As a consequence, a first step of reciprocal commitment, formal contractual safeguards and/or exchange of hostages (Williamson 1985) can be necessary in order to provide a stable window of the future (Bureth and *alii*, 1997). Reference to the formal document will be less and less necessary when the collaboration evolves and grows through time. Informal rules progressively substitute for formal explicit contractual terms.

The emergence of relational capital and tacit collective routines, as well as learning in general, also requires relatively frequent direct interactions between the participants, such as the implementation of specific communication channels. The implementation of an effective interaction process is an especially important prerequisite if collective, indivisible competencies and specific assets have to be created. The creation of a joint facility may have to be programmed in this perspective (as opposed to an *ex-ante* division of the tasks between the partners and a subsequent separate execution inside each member firm). Finally, the assumption that informal rules preserve flexibility requires some qualification: relational capital encoding in repetitive routines also introduces the possibility of inertia in the long run. In sum, a cautious balance between formal and informal mechanisms has to be maintained during the whole life of the collaborative relationship (Ring and Van de Ven, 1994).

However, the contractual aspects also crucially depend on the size of the projects. Size increases the administrative and coordination costs of running the project. In addition, an “excessive” number of participants may bring a greater likelihood of social loafing and free riding, thereby decreasing the extent of learning (Gibson & Vermeulen, 2003; Wong, 2004) and hence the likelihood of project success. For example, Stuart (1998) argued that the most successful alliances

are those between firms with similar technological foci and/or operating in similar markets, whereas in contrast, distant firms find it difficult to cooperate effectively.

4 Rationales for public funding of private R&D

4.1 Theory

In this part we will present different theoretical approaches analyzing the rationales for public funding of private R&D: the market failure approach, the structuralist-evolutionist failures, the multi-level and multi-agent approaches and the policy diffusion and imitation.

4.1.1 Market failures

In line with the "input/output" way of reasoning, innovative activity is performed by an innovator using inputs to produce technology, which is regarded as information. The argument put forward by (Arrow 1962) and (Nelson 1959) is roughly as follows: the peculiar activity of innovation and the good resulting from it do not show the "adequate" properties that the theory requires, optimizing the decision of the agent. There are indivisibilities in both the inputs and the outputs. The output is uncertain and may take a long time to realize, as well as being a non-rival and non-excludable good, it is non-appropriable.

The consequence is the well-known "lack of incentive" to innovate. The activity is costly, mostly because of its indivisibility characteristics. It is also risky, because of the uncertainty related, on the one side, to the final outcome and on the other side, to the level of demand resulting from the problem of price determination (according to the so-called "paradox of information", the buyer does not know the value of the information unless he buys it). Moreover, the economic gains are difficult to appropriate since they may benefit: i) consumers or clients, who have access to better products without necessarily being charged a corresponding increased price; this is the basis of the consumer surplus and "market" externalities; ii) competitors and the rest of the economy can use the technology produced by the innovator without paying anything, giving rise to "knowledge" and "network" externalities. In other words, the private rate of return to the potential innovator is too low for him to make further investments, although the social rate of return for the rest of the economy may be high. In this situation, the resource allocation mechanisms that are at the heart of the neo-classical approach do not work i.e. they do not generate the socially optimal situation: the investment in innovative activity is inferior to its socially optimal level because of these "market failures".

To remedy this situation the State can implement a set of corrective actions:

- To provide or help circulate better information on results, use and demand in order to reduce uncertainty, public programs can impose the disclosure of some pieces of information.
- To cope with the previously mentioned incentive problem of under-investment in R&D, public programs often contribute directly to the firms' investment in R&D by the means of a subsidy in order to share the risks and reduce the costs of innovation.
- To provide property rights to the innovator for his technology as a compensation for generating externality knowledge.
- To promote cooperation between users and producers of technology (vertical cooperation) in order to share market externalities, costs and diminish the uncertainty.

- To promote cooperation between producers of technology (horizontal cooperation) in order to share knowledge externalities. the costs and risks associated with the production of technology. Sharing R&D costs and other cost minimizing concerns are central in the traditional economic analysis of cooperative R&D, as proposed by scholars in industrial organization (D'Aspremont & Jacquemin 1988; Amir 2000; Katz et al. 1990; De Bondt 1997; Salant & Shaffer 1997). In this literature the partners generally hold homogeneous capabilities, are competitors and collaborate for cost minimization motives.
- To overcome R&D indivisibilities and to reach a Critical Mass of resources by pooling similar resources. Public programs also make it possible to avoid the duplication of research efforts.

4.1.2 Structuralist evolutionist failures

In this second broad approach, innovation is not considered as information anymore, but as a complex process in which resource and knowledge creation become central. This framework acknowledges the importance of the learning capacity of agents and groups of agents. This does not only embrace a capacity to learn something that would exist somewhere, but also the capacity to create new knowledge. This happens especially by changing ways of thinking, beliefs, visions, routines, etc. In terms of innovation, cognitive capacity concerns not only scientific and technical knowledge, but also the complementary knowledge required along the innovation process. This has some decisive consequences on appropriation and diffusion phenomena: for example, learning is obviously a cumulative and collective, rather than a purely individual process. This logically leads to an acknowledgement that it is a context-dependent process, which varies from one agent, group of agents, firm, industry, regions, institutions, etc. to another.

In this learning-oriented framework it is not possible to define an optimal situation, but it is sometimes possible to assess *ex post* if one situation is preferable to another. Referring to a tradition of research based on Schumpeter's cycle analysis, as well as on the evolutionary Nelson-Winter line of works, we assume that:

- the technological system follows some trajectory induced by a paradigm, therefore it must be able to exploit a "good trajectory" as well as to ensure a "good transition" from one paradigm to another;
- in order to be able to do so, in the whole system and at all levels of the system, there should be sufficient diversity to allow the selection processes to perform satisfactorily;
- this should be accomplished without too much loss of cohesion, which would unbalance the system and/or prevent it from evolving well;
- the basic engine that allows for all of this would be the maintenance of, or increase in, the cognitive capacity of all agents or groups of agents at all levels of the system.

With an approach in which all phenomena and processes are so complex and intrinsically related, it is rather difficult to identify and especially isolate "gaps". Within this alternative framework, the reference to an optimal situation does not exist and it is thus not exactly appropriate to consider "failures". One should rather consider "traps", "dysfunctions", "gaps", or "holes", leading to "dilemma and trade-offs" between existing forces driving the system, rather than "dilemma and trade-offs" between two possible states of the system (as choosing between two "second-best" situations). Various authors have already pointed to some of them (Malerba 1996; Smith 1996; Lundvall & Borrás 1997; Metcalfe 1998; Teubal 1998), but there is no unified and unanimously

accepted list of failures in the evolutionary constructivist framework. However, we assume here that what matters are, generally speaking[2]:

- "learning failures", i.e. problems that limit (or constrain the use of) the cognitive capacity of agents and groups of agents,
- "Systemic failures", i.e. a lack of coordination between the cognitive activities of agents or groups of agents.

4.1.2.1 Learning failures

Based on the above analysis, the basic principle of State intervention should be to help the development and the orientation of the cognitive capacity of actors and provide conditions conducive to the use of this capacity. The aims developed by the State could be the following:

- To better disseminate knowledge among the actors via training programs, which would allow to change the available knowledge base of different agents, increase the codification of knowledge and its transferability and to modify the distribution of knowledge
- To reinforce or sustain exploration activities. In a turbulent environment, organizations should maintain an appropriate balance between exploitation and exploration (Nelson 1959; March 1991). Both activities are critical but compete for scarce resources. Most of the time the refinement of existing trajectories is favoured by firms to the detriment of the discovery of new technologies, because of the temporal and spatial proximity of exploitation learning. R&D cooperation and subsidy could well represent an efficient way to compensate this kind of overexploitation, path dependence effect.
- To increase or change the absorptive capacity (Cohen & Levinthal 1990) of the agents, i.e. not only its ability to be aware of and identify external relevant knowledge and technology but also its capability to integrate, assimilate and recombine internal and external knowledge to address technical or organizational issues. Again, R&D cooperation and subsidy are efficient ways to modify the absorptive capacity of firms.
- To ease the access to and the combination of complementary assets and knowledge, to create new value. Complementarity is often a necessary - but not sufficient - condition for exploiting and benefiting from a technological innovation (Teece 1986). In his seminal contribution, Richardson (1972) already suggested that complementarity was the essence of inter-firm cooperation. He proposed that dissimilar, but closely complementary activities had to be articulated ex ante via inter-firm cooperative mechanisms, whereas similar activities (based on the same human capabilities) could be carried out within the frontier of the firm.
- To ease the access to and the association of similar resources and competences in order to reach a Critical Mass of resources able to trigger learning. Knowledge develops according to a snowballing effect: once the process of knowledge creation is launched it grows cumulatively, but it first requires a sufficient mass to start.

4.1.2.2 Systemic failures

Coordination of actors is a prerequisite to stimulate learning: a lack of coordination could for instance impede access to complementary knowledge and thus the creation of new value. Even if all the failures could *in fine* be expressed in terms of learning and cognitive problems, we contend

[22] In this paper we will not consider the so called "selection failures", corresponding to cases where the selection process does not operate properly, for instance when a given technology is eliminated too rapidly or maintained too long.

that the coordination of actors has its own difficulties. We will distinguish between coordination failures at three different stages: before the partnership has started, during the R&D project and after the end of the project (long term stability). To overcome the barriers linked to these three phases, the State can implement the following actions:

- To help potential participants, to find new partners, and to develop their networking strategy. Some potentially fruitful partnerships never emerge because the different actors have no information about the "know-who". This can be overcome by diffusing information about the participants and their projects, but also by inducing partners to form large consortia. Diffusing information is also a way to highlight the technological skills of participants.
- To provide the conditions for a stable partnership without impeding learning possibilities. Spontaneous collaborations are known to be highly instable. The public intervention can impose a set of minimal rules that have to be respected by all the partners. It can also support consortium management activities. This pre-defined collaborative framework eases the coordination of partners in terms of allocation of resources (money, skills, tasks, property rights), reduces the negotiation costs and contributes to building the channels used to create new knowledge. Nevertheless, the policy maker should ascertain that this ex-ante specification of rules does not entail learning rigidities.
- To favour long term relationships in domains where the government wants to sustain or create centres of excellence. The latter needs a certain duration to emerge, an increasing commitment from all partners (including the government) and a concentration of resources. This should be done to better exploit a "good trajectory", but not too long to avoid being locked-in.

4.1.3 Multi-level governance and multi-agent approaches

Multi-level governance is a concept developed by Hooghe and Marks in the 1990's and relates to the analysis of European integration and to the creation of new structures put in place by the EU in that period. The multi-level governance concept reflects the existence of intertwined levels of political decision-making processes located at different territorial levels. Multi-level governance was developed to analyze EU policy related questions and is used to study EU decision-making.

STI policies are implemented and designed at different territorial levels: supra-, sub- and national levels. The main idea in this stream of literature is that the role of national government in the setting up of STI policy has been eroded by a shift in supra-national governance and by the increasing importance of regions and other sub-national actors in innovation policy making. The creation of the European Research Area underlines an increasing supra-national level of governance. Among others, the ERA aims at opening and coordinating European, national and regional research programs in order to foster high level research and to address major scientific and technological challenges collectively.

Multi-level governance theory considers European Union as a complex political system with intertwined institutions existing at different levels and with specific policy characteristics. The European Union is composed by a European tier, a National tier and a Regional one. The multi-level governance approach focuses on the interaction between these different levels of governance and actors. It has a vertical dimension, which refers to the links between governments located at different territorial levels (including their institutional, financial and informational aspects) and a horizontal one which refers to relations between regions or between municipalities (Bache & Flinders 2004). These approaches describe how supranational, national and sub-national

governments are entangled in complex policy networks. They raised important issues about the role, power and authority of states.
Some authors underline reasons why member states lost their ability to control supranational and sub-national institutions: partial autonomy of member institutions, unequal access to information, shifts in national decision-making preferences. National and European institutions being disconnected it becomes difficult for member states to reconcile their domestic interests to the supra-national ones. “Each level of actors hold important resources, such as information, political power, expertise and prestige and all are engaged in a bargaining relationship” (Perry 2007, p.1053). The existence of policy networks implies negotiation and dialogue between the actors (state and non-state ones) instead of hierarchical and controlling relations. However, the questions of authority and asymmetry of power remain central to the analysis (Crespy et al. 2007).
More generally multi level governance is often criticized for its lack of robustness as an analytical tool (Jordan A. 2001) and its difficulties to be operational. It is not really a proper theory with its explaining power. It is rather an approach which helps to structure the analysis, within a geographical area, of the relations between different political actors and institutions located at different territorial levels. This approach focuses on issues related to the allocation of decisional responsibilities, the possible existence of conflicting policy objectives, bargaining processes, etc. It analyses the nature of exchanges, the distribution and management of resources and the relations between actors within each level of governments.

4.1.4 Policy diffusion and imitation

For the policy diffusion literature, policy innovation occurs whenever a government adopts a new policy (Shipan & Volden 2008). This innovation might be due to pressure coming from internal factors such as national interest groups, electoral forces or from external elements as a another government. The second process is called policy diffusion: a decision-maker adopts or imitates an innovation created elsewhere. Many studies have analyzed the processes of diffusion and thus the factors fostering or hampering the process (Volden 2006). Shipan and Volden (2008) focus on four mechanisms explaining why a policy spreads from one government to another. The four mechanisms of diffusion are learning, economic competition, imitation and coercion. It is easier to learn from a policy which has been implemented in several countries and the adoption will depend on its success in these countries. Second, the propensity of adopting a policy increases if there are positive spillovers from nearby countries. For instance, if the adoption of a standard infrastructure has positive spillovers, than policy makers will probably adopt the others policy. Third imitation is often seen as a diffusion mechanism. Imitation somehow supposes that one aspires to be like the neighbour. The literature highlights that innovative leaders are larger and wealthier and that smaller actors aim to be like the leaders (Grupp & Richards 1975). Adopting a policy increases when the bigger neighbours have adopted the same policy. Finally, in the international arena, countries can coerce other countries to press them to take actions either directly or through international institutions (UN or IMF).
In Europe, the EC and several European governments set up STI policies and programs during the 1980’s. The national initiatives were centred towards domestic issues but were also part of a more European oriented STI policy. Mörth (1997) underlines that in the 1980’s the national policy processes were very similar in Sweden, France, Germany, UK and at the European level. Her analysis suggests that this convergence of national and European policies is explained by policy diffusion. The diffusion process might be promoted by agents of diffusion such as bureaucrats who belong to a complex international political-administrative network, by political and economic

internationalization which increases the contact between policy makers, by structural similarities between countries etc. Very often in the policy diffusion theory diffusion takes place in complex transnational political networks and is based on a rational actor model: the policy makers import consciously a policy from another country. In the European arena, European integration takes place in a complex multi-level space and thus it is difficult to isolate the first mover and the receivers of the policy innovation. The rational actor model can barely explain this phenomenon. According to Mörth (1997) in the European STI context, diffusion is mainly explained by contacts and communication channels which ease the connections of the various European countries. The multilevel governance structure of the EU most probably helped to enhance the communication and thus policy diffusion.

4.2 Rationales in context: the European Framework Programs and ERA-NET as means of funding collaborative R&D

The European Framework Program has shifted its goals and focus since its kick-off in 1984. The first three FPs (1984-1994) concentrated on achieving competitiveness of high-tech industries and pursued technology-push objectives. These framework programs were created mostly of market failure arguments and their main aim was to share cost, to create a Critical Mass and to internationalize knowledge spillovers.

In the mid of the 1990's, FP4 and FP5 (1994-2002) moved their objectives and concentrated on knowledge diffusion, on offering a large part to the participation of SMEs as important innovative actors in Europe, and on user-oriented technologies. Training and mobility of researchers started at that period. FP5 introduced a major change with its thematic programs (quality of life, user friendly information society, competitive and sustainable growth, energy, environment and sustainable development) aiming to answer to broad socio-economic questions.

FP6 shifted towards developing scientific and technological excellence in order to create the European Research Area (Roediger-Schluga & Barber 2007). Reaching excellence and creating the ERA are explicit goals in FP7. FP7 built four different programs to support research: Cooperation (funding of cooperative research project in sub-programs organized around 10 defined themes), Ideas (the European Research Council will support excellent individual researchers across all scientific and technological areas), People (Marie Curie actions to support the mobility of individual researchers) and Capacities (creation of research infrastructures, supporting SMEs, international cooperation, regional capabilities etc). The Cooperation program is the biggest in monetary terms and its aim is to support transnational cooperation in order to improve research excellence in Europe. It is implemented through different action: collaborative research, coordination of national research programs (ERA-NET, ERA-NET PLUS, Article 169), Joint Technology Facilities and Technology Platforms.

FP5, FP6 and FP7 use a variety of instruments to support cooperative R&D. These instruments are supposed to answer to specific failures mentioned above. All the following instruments are not present in each FP but were present in at least one. The description of the instruments is the one made by the Commission on the CORDIS Website.

Integrated projects (IP): Their aim is to create new knowledge in some priority themes by funding ambitious, multidisciplinary, long-term and risky projects with different research issues. This suggests that they are highly exploratory and combine complementary resources. Moreover they involve the whole spectrum of research activities from basic to applied research and aim at reaching a Critical Mass of activities, resources and expertise. The EU funds RTD, including

innovation related activities like dissemination and exploitation of the results. It also supports demonstration, training (internal to the project) and consortium management activities.

Specific Targeted Research Projects (STREPS) and Shared Cost Actions (CSC and CRS): Less ambitious than IP, these projects deal with objective-driven research and thus are more focused than the former. They usually concern single research issues and activities, are mono-disciplinary and assemble a smaller Critical Mass than IP. As suggested by their name, cost sharing is one of their main purposes. The EU supports RTD and/or demonstration activities, innovation-related and consortium management, but no training. The target audience consists primarily in organizations active in the research field: companies, research institutes and universities.

Network of Excellence (NoE): Their aim is to strengthen scientific and technological excellence on a particular research topic, through the durable integration of a limited number of research institutions. Reaching a Critical Mass and avoiding the fragmentation of existing research capacities are expected to promote scientific European leadership and excellence. The EU provides subsidies for supporting the following activities: integration and joint research programs, activities linked to "spreading excellence" like external training and dissemination, and activities linked to consortium management.

Coordination Actions (CA) and Thematic Networks (THN): These actions do not provide direct support for RTD activities, but they aim at promoting the integration, coordination and networking of European research for a specific objective and for a fixed period of time (between 18 and 36 months, no durable integration). The EU funds coordination activities that complement other FP instruments (conferences, exchanges of personnel, standardization), as well as training and consortium management activities.

Specific Support Actions (SSA) and Accompanying Measures (ACM): More limited in scale than CA and THN, these actions aim at favouring coordination between a small number of partners or even a single participant. More precisely these instruments do not provide direct subsidies for RTD, but they fund the so-called "support activities", i.e. activities linked to the implementation of FP, the dissemination of results and the preparation of future RTD activities.

Specific project for SMEs (COOP/COLL): They aim at promoting the participation of SME, through the funding of RTD carried out on common specific projects, or of actions performed on behalf of industrial associations or groups of researchers where SMEs are prominent.

Coordination, multi-disciplinarily, reaching a Critical Mass of resources, activities and expertise, promoting scientific excellence and leadership, avoiding fragmentation of existing research capacity are crucial elements underlined in the objectives of these different instruments.

Bach et al. (2009) analyzed, thanks to the data generated by the Inno-impact project, the motivation of firms to participate to a specific instrument.

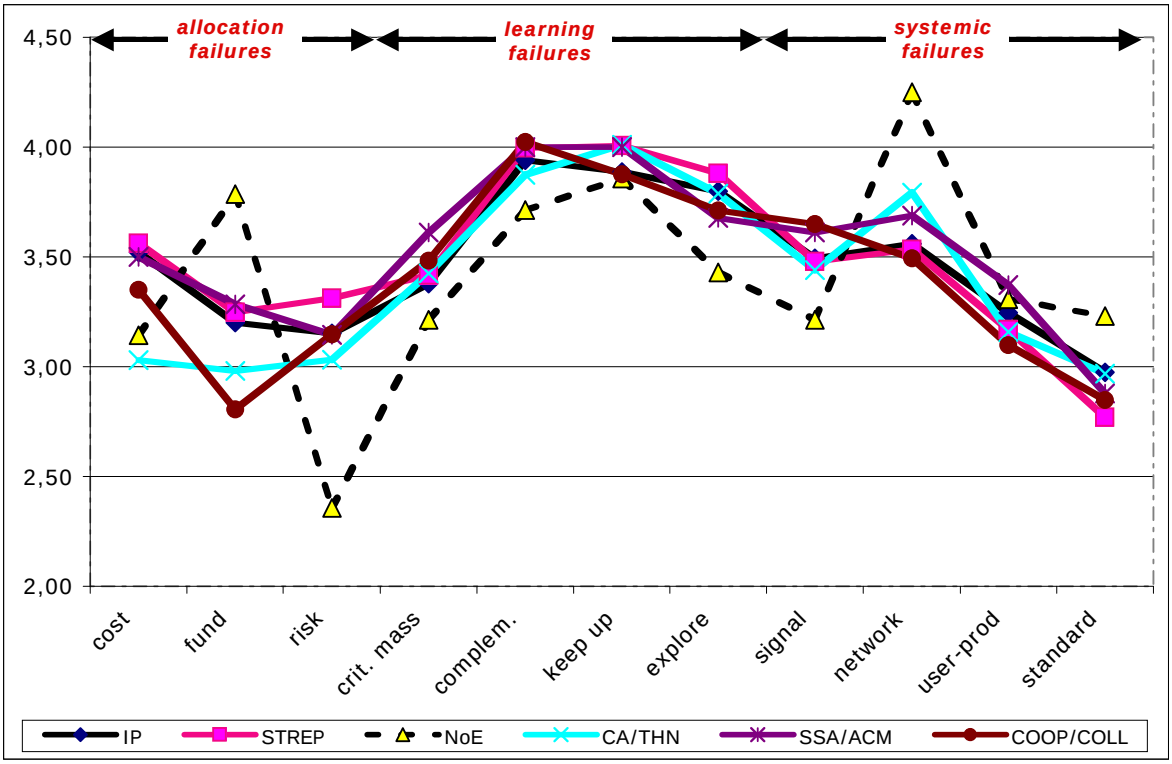


Figure 2: Detailed motivations of firms for participating in each FP instrument (average mark estimated by the whole sample of firms for each objective, by type of FP instruments)

(between 1 222 and 1 292 answers depending on the FP instruments and the objectives: IP 159 to 168 ; STREP: 817 to 865 ; NoE: 12 to 14 ; CA/THN: 94 to 106 ; SSA/ACM: 55 to 62 ; COOP/COLL: 79 to 84)

The analysis of the motives of respondents for participating in a specific FP project underlines the idea that firms do not enter FP projects because they need to reach a Critical Mass and/or to share similar resources. The answers “access to complementary resources and skills”, “keeping up with state of the art technological developments" largely dominate all answers. Market related motives and cost/risk sharing ones are not the main reasons why the companies decide to participate to FP projects. This ranking is stable over different categories of participants and holds across FP5 and FP6 projects, with only slight differences among FP instruments. Policy makers should consider knowledge complementarity as a critical issue and cost-sharing issues should be given less importance. The way consortia are structured (firms from diverse industries, associating users and producers) certainly influences the outcomes and thus the impact of the public policy.

The ERA-NET scheme follows the same type of objectives as FPs and it aim is “to develop and strengthen the coordination of national and regional research programs through two specific actions:

- ‘ERA-NET actions’- providing a framework for actors implementing public research programs to coordinate their activities e.g. by developing joint activities or by mutually supporting joint calls for trans-national proposals.
- 'ERA-NET Plus actions'- providing, in a limited number of cases with high European added value, additional EU financial support to facilitate joint calls for proposals between national and/or regional programs.

Under the ERA-NET scheme, national and regional authorities identify research programs they wish to coordinate or open up mutually. The participants in these actions are therefore program 'owners' (typically ministries or regional authorities defining research programs) or program

'managers' (such as research councils or other research funding agencies managing research programs).” http://cordis.europa.eu/fp7/coordination/eranet_en.html
Cooperation between different partners of the innovation system is a crucial element of the European RTD policy and it is tightly linked to the systemic failure mentioned at the beginning of this part. In other words, the analysis of the achievement of a Critical Mass in the ERA-NET programs will have to take into account analytical issues related to cooperation: trust, absorptive capacity, pooling complementary resources, learning ability, transaction costs, risk and cost sharing etc.

5 Science, Technology and Innovation Programmes performance

In Science, Technology and Innovation policies, the most dominant type of policy measure are programmes offering direct funding for R&D and related activities. Knowing about the performance of programmes becomes more important the more money is spent for a particular measure. In recent years, increasingly large amounts of money are being spent for STI policies in order to move to what has been termed in the European context a “knowledge-based society”. Since European leaders expressed this goal numerically in their 2000 Lisbon strategy, stating they wanted to increase the share of RTDI spending up to 3% of the Union’s GDP, national governments have invented a number of new policy measures to foster this goal. Assessing how well a programme performs its intended functions is of increasing importance “as a way of demonstrating accountability to the public and the program stakeholders” (Rossi et al. 1998, p.191).
Programme performance is the central topic of STI policy evaluation. This chapter draws mainly on the evaluation literature. It focuses on conceptual and methodological issues of programme performance. The evaluation literature is in large parts related to national funding programmes, where the objective of reaching “Critical Mass” is generally not applicable. Where available, this chapter refers to (generalized) knowledge about programme performance, in particular with a view on evaluation methodologies which allow assessing the performance of “meta-programmes”. These programmes, which do not offer direct R&D funding, but try to establish new forms of STI policy at European level. These instruments aim at pooling resources and coordinating activities at European level. Examples include “Networks of Excellence”, “Integrated Projects”, “ERA-NETs”, “Joint Technology Initiatives” or “Joint Programming”.

5.1 Defining programme performance

Programme performance is a very general term in the evaluation context. The purpose of an evaluation is to focus on specific dimensions of performance and to assess the performance against a certain standard chosen for each dimension.
Typical performance dimensions are (Rossi et al. 1998, p.87):

- The need for the program (challenge to be addressed, characteristics of target group, nature and magnitude of problem, etc.)
- Program conceptualization or design (organization and implementation in order to address the needs)

- Program operations and service delivery (issues of implementation process, client satisfaction)
- Program outcomes (goal attainment, side effects)
- Program cost and efficiency
- Many different standards – or performance criteria – might be relevant to program performance such as (Rossi et al. 1998, p.78, 84):
- The needs or wants of the target population
- Stated program goals and objectives
- Professional standards
- Customary practice, norms for other programs
- Legal requirements
- Ethical or moral values; social justice, equity
- Past performance, historical data
- Targets set by programme managers
- Expert opinion
- Pre-intervention baseline levels for the target population
- Conditions expected in the absence of the program (counterfactual)
- Cost or relative cost

5.1.1 Performance dimensions relevant for "meta-programmes" at European level

Programme performance is a very general term in the evaluation context. The purpose of an evaluation is to focus on specific dimensions of performance and to assess the performance against a certain standard chosen for each dimension.

Programmes or initiatives at European level which aim to coordinate national programmes in order to pool resources follow the rationale of reaching "Critical Mass". However, this is not an end in itself. "Critical Mass" shall allow achieving certain results. In this view, Critical Mass could be viewed as contributing to the **performance dimension** of **goal attainment**. Often, reaching at outcomes, which are defined as more persistent results at the level of programme participants and beneficiaries, is central to goal attainment. These outcomes can appear in different forms of **additionality**.

The following sections give a short description of how these concepts are being understood and used in the context of programme evaluation.

5.1.2 Goal attainment

Performance in the meaning of goal attainment addresses different types of effects: outputs, outcomes and impacts. The literature shows a variety of definitions for these terms, distinguishing between the timing (short-, mid- and long-term), persistence (non-persistent vs. persistent), spread (i.e. at the direct level of participants or at the indirect level, i.e. beyond the participants), and dimension (economic, technological, scientific, social or environmental effects).

We understand the different aspects of goal attainment of STI programmes in the following way (Rhomberg et al. 2006, p.12, 14; Daimer & Bührer 2010; Fahrenkrog et al. 2002, p.17):

- **Outputs**: Short-term (measurable) results of funded projects (patents, publications, products, prizes, increase in turnover, reports, prototypes, business plans, new partnerships …).

- **Outcomes**: Persistent effects on the participants of the programme, observable most often rather mid- to long-term, such as improved performance, new networks or awareness-creation, changed attitudes towards innovation, risk or management. Some outcomes are measurable (e.g. citation rates), some are more difficult to measure. One possible approach for quantification is the concepts of input and output additionality. Evolutionary and learning effects can be measured (qualitatively) using the concept of behavioural additionality (see below).
- **Impacts**: (Mid- or long-term) Indirect effects, i.e. beyond the participants of a programme (spillovers), e.g. economic effects such as new jobs, or social effects, such as new networks (including actors not funded by the programme) or awareness-creation and changed attitudes in society towards innovation, risk or management.

Important questions in this context are,

- Whether the observed effects have been intended by the programme, and
- Whether the observed effects can be attributed to the programme, i.e. whether the programme has contributed to the observed effects (or whether the effects have (also) been caused by other factors).

This last question is important for impact assessment, however it is methodologically difficult to achieve, as it needs comparison with the counter-factual situation, i.e. what would happen in the absence of the funding (Miles & et al. 2005, p.143; White 2009). The additionality concept is one possible means to approach this topic.

5.1.3 Additionality

Additionality basically means a value-added of a programme. Additionality addresses the issue whether public funding results in additional activity rather than replacing (private) support that would have occurred in the absences of the intervention. Today, three concepts of additionality are being discussed in the evaluation literature (Georghiou 2002).

"The concepts of input and output additionality are widely considered as the hallmark of the neoclassical policy rationale which ultimately seeks to remedy the market failure by re-instating the second-best. Therefore, any policy with neoclassical rationale should create input and/or output additionality. On the other hand, behavioural additionality is considered as the core of the evolutionary/structuralist view which urges policy action to overcome system failures. In this view, a policy action is successful only if it changes the persistent behaviour of the agents, i.e. creates behavioural additionality" (Gok & Edler 2010; Bach & Matt 2005; Bach & Matt 2002; R.G. Lipsey & K. Carlaw 1998; Richard G. Lipsey et al. 2006).

- **Input Additionality**: The issue, whether funding complements or substitutes their own expenditures or other funding resources. Funding, which acts as a substitution has to be considered as "deadweight".
- **Output Additionality**: This measure can be understood as referring to outputs which would not have been achieved without the funding in question. However, outputs face the problem of potential non-persistence. For this reason, outcome additionality is a possible alternative, however harder to measure.
- **Behavioural Additionality**: There are four possible ways of understanding behavioural additionality (Gok & Edler 2010; Gok 2010). (1) Behavioural Additionality can be seen as an extension to Input Additionality, i.e. a non-persistent additional R&D activity. (2) Behavioural Additionality is in the view of a second group of researchers the change in the non-persistent behaviour related to R&D and innovation activities, i.e. a change in the way

R&D is being carried out. (3) A third understanding is similar to the second, however assumes that the changes in behaviour related to R&D and innovation activities are persistent. (4) In its widest understanding Behavioural Additionality describes persistent changes in the general conduct of the researcher or research institution, including organizational routines, cognitive capacity and learning (Bach & Matt 2005).[3]

Additionality is being addressed as **an issue in EU programmes**, in particular input additionality and behavioural additionality. In the way of the first understanding of behavioural additionality, these two types are not really distinguishable. "Input additionality and behavioural additionality are usually merged together in a question that lists different degrees of additionality, whether the R&D would not have been carried out at all without public support, or alternatively whether the public funding changed the scale and scope of the R&D or R&D would have been done differently" (Luukkonen 2000, p.713). Others think of more persistent effects such as the persistence of networks beyond projects when talking about behavioural additionality, i.e. a concept being separate from input additionality. "If Europe's knowledge leaders were already collaborating with each other since the first few FPs, then what was and is the added value of the Networks of Excellence and (to a lesser extent) of Integrated Projects?" (Delanghe & Vanslembrouck 2007, p.105) Additionality has been also an issue in the evaluation of the ERA-NET scheme, however not explicitly at the level of different additionality types. The aspects mentioned in the report again refer to Input and Behavioural additionality mainly (Juhlin et al. 2009).

5.2 Methods to assess Performance or Impact

Depending on the kind of performance criterion that seems appropriate for evaluating a certain performance dimension (see 2.5.1), specific evaluation methods can be applied. For impact assessment many of the mentioned criteria have been translated into certain methods. However, it seems that not all of the methods suit the evaluation of different policy instruments. For example, while econometric analysis might be well suited for funding programmes aiming at economic success of the beneficiaries on new (innovative) markets, they are rather irrelevant for "meta-programmes" which have more outcome- and impact-related objectives. Table 1 gives an overview on the suitability of certain methods for the evaluation of specific policy instruments. This table is from the RTD Evaluation Toolbox (2002), which does not only consider instruments at national level, but also "networks of excellence (NOE)" and "integrated projects (IP)" as new-type instruments for coordination and pooling resources at European level.

[3] They suggested to view this as a fourth type of additionality, cognitive capacity additionality.

	Innovation surveys	Econometric models	Control Group approaches	Cost Benefit Analysis	Expert Panels/ Peer Review	Field / Case Studies	Network Analysis	Foresight/ Technology Assessment	Benchmarking
Financing R&D	•••	•••	•••	•		•••		•	•
Provision of R&D infrastructure		••		•••	•••	•••	•••	••	•••
Technology transfer / innovation diffusion	•••	•••	•••	••	•	••	•••	•••	•••
Legal frameworks (IPRs, standards and regulation)	•	•	•	•••		•••		••	•••
Integrated projects			•	•••	•••	•••	•••	••	••
Networks of excellence					•••	••	•••	••	••
Legend: ••• Highly suitable •• Suitable • Less suitable									

Table 1: Evaluation Matrix: Matching policy instruments and methods (Fahrenkrog et al. 2002, p.16)

From this table,

- **Expert panels/ Peer reviews** and **Network analysis** are the two methodologies highly suitable to either IPs or NOEs;
- **Cost/Benefit analysis** and **Field/case studies** are highly suitable methodologies for evaluating IPs;
- **Foresight/Technology Assessment** and **Benchmarking** can be suitable for the evaluation of both instruments.

These methods are shortly described in table 2 below. Their application depends often on the timing, as some of them are more suited for ex-ante impact assessment such as Cost/Benefit analysis or Foresight processes and some are ex-post applications such as network analysis, case studies or benchmarking. They have also different data requirements, strengths and limitations.

Methodology	Type/ Use	Data requirements	Strengths	Limitations
Expert panels / Peer reviews	Qualitative Semi-quantitative *Ex-ante* *Monitoring* *Ex-post*	Project programme data	Evaluation of scientific merits Flexibility Wide scope of application	Peers independence Economic benefits not captured
Network analysis	Qualitative Semi-quantitative *Ex-post*	Project programme data	Comprehensive empirical material Co-operation linkages	Time involved in collecting the survey information
Cost/Benefit Analysis	Quantitative (with qualitative elements) *Ex-ante (especially)* *Monitoring* *Ex-post*	Micro data Profit & Cost estimates	Provides an estimate of socio-economic effect Good approach to assess efficiency Addresses all economic assumptions (by making them explicit)	Requires high technical capacity Depends on assumptions made Careful interpretation of results when benefits are not easily quantifiable in monetary terms
Field/Case studies	Qualitative Semi-quantitative *Monitoring* *Ex-post*	Project programme data	Observation of the socio-economic impact Exploratory and descriptive strengths Consideration of context	Results not generalizable
Foresight / TA	Qualitative Semi-quantitative *Ex-ante* *Monitoring*	Qualitative data Scenario	Consensus building to reduce uncertainty under different scenarios Combination of public domain and private domain data Articulation and road mapping of development of new technologies	Impossibility to detect major R&D breakthrough
Benchmarking	Semi-quantitative *Ex-post* *Monitoring*	Science and Technology indicators	Comparison method across different sectors Support to systemic evaluation of institutions and systems	Data detail requirements Non transferable

Table 2: Evaluation Methodologies (Fahrenkrog et al. 2002, p.69)

For example, the evaluation of the ERA-NET scheme under FP6 has used the following methodologies: descriptive network analysis, country and thematic case studies, bi-variate analysis of data from participant surveys (Juhlin et al. 2009).

5.3 Measurement of programme performance

The evaluation and impact assessment of the ERA-NET scheme (Juhlin et al. 2009) has provided an overall insight into performance measurement of R&D programme cooperation at European level and paved a way for future impact assessments of this kind of policy instrument. The effects have been assessed at the levels of the overall scheme, of country groups and of themes.

Citing the evaluation report (Juhlin & et al. 2009, p.13), the study aimed to answer the five overarching research questions:

- Q.1: To which extent, and how, FP6 ERA-NET participation had an effect on the landscape of publicly funded national/regional research programmes in certain targeted EU countries?
- Q.2: To which extent FP6 ERA-NETs had a structuring effect in certain targeted research fields that ERA-NETs addressed?
- Q.3: Which direct benefits and indirect benefits have been generated through the ERA-NET scheme in FP6 and how can the impacts be measured for both types of benefits?
- Q.4: Have FP6 ERA-NETs helped to mutually open up national programmes in ERA? If yes, to what extent and what is needed to assure that this result becomes a durable lasting effect within ERA?
- Q.5: What are the lessons learned for all possible stakeholders and where can these lessons be traced?

The study focused on the following list of effects:

Outputs: the tangible and intangible result of joint activities including:

- Pilot calls: joint calls for proposals that were meant to test procedures for further cooperation;
- Joint calls: funding of activities as a result of a call for proposals organised jointly by ERA-NET participants;
- Joint programmes: a programme organised jointly by ERA-NET partners and funding a set of activities or research projects with an explicitly defined scientific objective involving several countries; and
- Intangible outputs including non-quantifiable outputs as well as direct and indirect benefits.
    - creation of new networks, as well as deepening and expansion of existing ones;
    - new collaboration agreements within and outside the European Union;
    - greater understanding of R&D procedures in other countries;
    - development and adoption of new evaluation protocols and procedures;
    - opportunities for networking with other programme managers and programme owners and European scientific communities;
    - increased knowledge of scientific communities across Europe;
    - increased knowledge of, and cooperation with, funding agencies across Europe31;
    - new opportunities for transnational collaborative research;
    - creation of a 'Critical Mass' at European level for undertaking transnational R&D activities;
    - mutual learning about the design of joint activities between programme owners and programme managers thus enabling transnational R&D cooperation; and
    - creating a forum for discussing R&D policy and priorities in specific research fields at European level.

Outcomes: the impacts of the ERA-NET scheme at programme, national and European level including:

- 1st order outcomes reflecting the impact at national programme level:
    - national/international nature of R&D programmes,
    - national thematic priorities,
    - national R&D budgets,
    - the programme portfolio, and

- programming practices;

- 2nd order outcomes reflecting the impact at national policy level ("Opening up of national programmes", i.e. adoption at national level of the principle to fund also non-resident researchers):
  - committing funding contributions to a real common pot allowing the best proposals to be funded independently of nationality or place of residence,
  - "mutual opening up": implies that rules and procedures for supporting joint activities are aligned between programmes from different countries in a systematic manner, and
  - extent to which national programmes enable national researchers to participate in a transnational project funded nationally (typical approach for virtual common pot calls);
- 3rd order outcomes reflecting the impact at European level, particularly in relation to the ERA (structuring effect, i.e. "organisation and configuration" of the fabric of research in Europe via the improved coordination of national and regional research activities and policies with a view to focus and further integrate research in Europe):
  - better information on ongoing research funding and research activities in Europe,
  - combined effect of identifying compatible national and regional programmes in Europe, and establishing a 'Critical Mass' of resources in particular areas. These would have been as follows: strengthening of excellence through competition at European level and via transnational collaboration, and through exercising a catalytic effect on national initiatives and improving the coordination of activities of Member States.
  - harmonisation of funding in specific research fields so as to deliver greater benefits for research beneficiaries.

The way "Critical Mass" is being used in this list could give the impression that Critical Mass has been understood by the evaluators as a means in itself. At the same time, this list of outcomes and outputs gives a first and already quite coherent insight into possible outputs and outcomes, which might be realized by a Critical Mass of resources.

6 Profile of the interviewed experts

Dr. **Andre Schlochtermeier** is head of the EU office at the DLR (German Aerospace Centre). The DLR is a project management agency which manages primarily research and innovation funding projects for the German federal ministries. For the Research Ministry (BMBF) it coordinates several programmes. The EU office at the DLR coordinates for the BMBF (Unit 213) EU-related activities, e.g. it coordinates all German activities in ERA-NETs.

Dr. **Wilfried Diekmann** is responsible for ERA-NETs in the EU-office and **Matthias Chardon**'s responsibilities cover Joint Programming. All three experts have broad policy knowledge and broad insight into research and innovation policy and funding at European level.

Dr. **Tasso Brandt** is a senior researcher at the Fraunhofer ISI. His main research areas are policy evaluation and the integration of the European Research Area. The main rationale for choosing

him as an expert is his involvement into the ERA-Dynamics project by the Prime Network of excellence. This project aimed to study the mutual ‚functional' interrelationship (or ‚congruence') between content-wise driven knowledge dynamics on the one hand and the development of institutional and governance arrangements on the meso- and macro-level of research (national and post-national) on the other. The main empirical focus was on the functioning of ERA-NETs. The expertise accumulated in this project is of direct relevance to this project on Critical Mass. Tasso Brandt has done empirical work on two ERA-nets under the FP6-framework in the field of chemistry: ACENET and ERA-chemistry. Mainly from this work he has crossed the rationale of Critical Mass in EU research policies on the one hand and the main drivers of the establishment and success of ERA-NETs on the other hand.

Dr. **Giorgio Sirilli**, economist and statistician, is Research director at the Institute for the Study of Regionalism and Self Government (ISSiRFA) of the National Research Council (CNR) in Rome. His research interests span the fields of science and technology policy, economics of technical change, science and technology indicators, management of innovation, human resources for science and technology, evaluation of research and development, spatial dimension of innovation. He is the author of more than 200 scientific publications and contributed to the drafting and to the development of statistical manuals on science and technology indicators (e.g. Frascati Manual). Consultant to public and private organizations in Italy and abroad, he is Italian delegate to committees dealing with science and technology policy issues at the OECD and the European Union. Director of various research projects, he is a member of the editorial board and referee of scientific journals, of the international organizing committee of the Series of International Conferences on Technology Policy and Innovation, and fellow of the IC2 Institute of the University of Texas at Austin.

Professor **Roberto Baldoni** has several years experience in research (from theory to practice) in the fields of distributed, pervasive and p2p computing, middleware platforms and information systems infrastructure. He is the founder of Middleware LABoratory (MIDLAB) and he has been PI of many national and European research projects. A partial list of his publications can be found at DBLP, at Scholar Google and at MIDLAB publication repository. Roberto Baldoni has been visiting researcher at INRIA, Cornell University and EPFL. He participated to the working group for the definition of the next generation systems for Italian e-government (Servizio Pubblico di Cooperazione). He regularly serves as an expert for the EU commission in the evaluation of EU projects in the security and dependability, embedded systems and e-government areas. On the projects side, he is a member of the Executive Board of the RESIST NoE, the coordinator person of the EU project SM4ALL[4] (on networked embedded systems) and the Technical co-chair of the EU project CoMiFin (on the protection of the financial infrastructure).

Professor **Nicola Mazzocca** is currently a Professor of High-Performance and Reliable Computing at the Computer and System Engineering Department of the University of Naples Federico II, Italy.
He has been scientific counsellor of the Ministry of Innovation from October 2006 until February 2008, when he became Regional Alderman for University and Scientific Research of Campania Region Administration. He finished his mandate on May 2010. He owns an MSc Degree in

[4] SM4ALL has been selected by the Italian Ministry of Innovation to be presented at Shanghai's Expo 2010 from July 24th to August 7th in the context of the exhibition "Italy Innovators".

Electronic Engineering and a Ph.D. in Computer Engineering, both from the University of Naples Federico II. He authored over 200 papers in international journals, books, and international conferences in the field of computer architecture, reliable and secure systems, distributed systems, and performance evaluation in high-performance systems. His research activities include methodologies and tools for design/analysis of distributed systems; techniques for modelling and analysis of distributed heterogeneous systems and communication networks; secure and real-time systems; distributed control applications; models and tools for configuration and performance evaluation of distributed heterogeneous systems and communication networks; dedicated parallel architectures. In the context of such activities, he took part in numerous research projects, funded by the Italian Ministry of University and Research (MIUR), the National Research Council (CNR), the Agenzia Spaziale Italiana (ASI), and the European Union. He cooperated with a number of Italian and foreign institutions, including the Universities of Torino, Firenze and Parma, the CNR, the University of Illinois at Urbana-Champaign, Caltech, the University of Sheffield, and the Jet Propulsion Lab (JPL). In 1990, he received - along with G.Franceschetti, A.Mazzeo, V.Pascazio, G.Schirinzi- the "Premio Philip Morris per la Ricerca Scientifica e Tecnologica" award[5]. Other awards include the eGate Bronze award 2005 and the Simagine Tim award 2005, sponsored by Axalto, STMicroelectronics, Sun Microsystems, and Samsung.

Marc Jacques LEDOUX received his PhD in applied organic chemistry and his PhD in physical sciences (1977) in Strasbourg, and had post-doc at Oxford University. He was Director of different CNRS/University joint labs in Strasbourg and Lille, and was responsible for the creation of one of the first European Lab (ELCASS). His research is in catalysis and catalysers, and has direct applications to industry (chemical and refining), de-pollution processes and new sources of energy and raw materials. He has overseen more that 150 industrial and academic oriented (including NoE), filed numerous patents, has worked as a consultant (Péchiney, Total, Du Pont de Nemours, Exxon) and has created spin-off companies. He published 200 articles and books, and received the Centenary Lectureships Award 2004 of the Royal Society of Chemistry. He also contributed to the development and the implementation (notably to EU programmes) of a new method for measuring the economic impact of research, and became involved with many French and foreign institutions: the Ministry of Research (as a representative to the European Commission in Brussels), the Council of Europe, the European Parliament, the French Planning Office and several other local, regional and national bodies. After being the head of the Chemical Sciences Department of the whole CNRS at HQ CNRS, he is now (since 2008) the Head of the Relations with industry at HQ CNRS, especially in charge of patenting, licensing and contracting activities of CNRS.

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[5] The award was assigned by "Ministero dell' Università e della Ricerca Scientifica e Tecnologica", by CNR and by ENEA for the project "IMAGO: una macchina a parallelismo distribuito dedicata alla elaborazione delle immagini da satellite".

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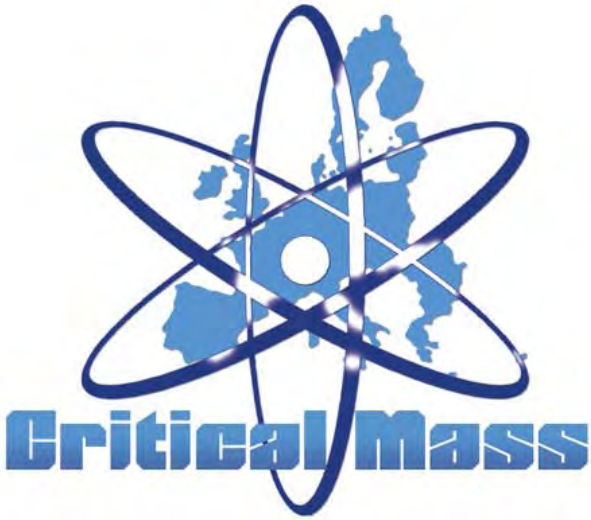
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A potential driver of joint programming



Annex 2

Analysis of the 13 selected ERA-NETs

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1 The ERA-NET AirTN

1.1 Introduction

Since 1973, the leading aeronautical nations in the EU have collaborated in an intergovernmental group called GARTEUR (Group for Aeronautical Research and Technology in Europe) which now includes France, Germany, Italy, the Netherlands, Spain, Sweden and the United Kingdom. Past and present research topics cover safety, avionics, certification, multidisciplinary design aspects, performance, stability and control, helicopters, structures and materials. The 7 GARTEUR countries make up the core of the present Coordination Action to set up an ERA-NET for aeronautical research. They are joined by government departments and public bodies (agencies, research establishments) from eight other EU Member States plus Romania and Switzerland, and together they represent every European country with a significant research programme in aeronautics.
The aims of the network – known as Air Transport Net (AirTN) – are twofold. First, it will step up co-operation and coordination between civil aeronautics research programmes building on the GARTEUR structure already in place. Second, it will extend that co-operation to a wider circle of countries, helping to establish an aeronautics presence in the European Research Area. AirTN is initially being funded for three years, but the partners intend that it will become the basis for lasting co-operation between Europe's aeronautical policymakers.
In the first place, GARTEUR was asked by the Commission to set up an ERA-Net in an effort to invite existing structures in Europe to make use of the new mechanism. This effort has brought about new collaborations and trust building beyond the core group of 7 member states.

Research field: Aeronautics
Sector: Transport
Overlaps with other ERA-Nets: There is no comparable or related ERA-Net.
Duration: 3.5 years in FP6: Jan. 2006 – June 2009, second phase in FP7 from Jan. 2010 – Dec. 2012.
EC funding: €2 790 000 (FP6, Source: CORDIS); from Ramboll: 559.380 € (coordination funding FP 6); 303.000 € (coordination funding FP 7)

23 Members from 17 countries in the beginning:
Coordinator: Germany: German Programme Management Office Aeronautics Research and Technology (DLR/PT-LF), together with the Federal Ministry of Economics and Technology (BMWi)
Partners:

1. Austria: Federal Ministry for Transport, Innovation and Technology (BMVIT)
2. Austria: Austrian Research Promotion Agency (FFG)
3. Belgium: Belgian Federal Science Policy Office Aeronautics (BELSPO)
4. Czech Republic: Ministry of Education, Youth and Sports (MSMT)
5. France: Ministry of Transport / Aeronautical Programmes and Cooperation Department (DPAC)
6. France: Aeronautics and Space Research Centre (ONERA)
7. Greece: General Secretariat for Research and Technology (GRST)
8. Ireland: Enterprise Ireland (EI)
9. Italy: Ministry for Education, University and Research (MIUR) – with support from the Italian Aerospace Research Centre (CIRA) as a third party contribution to the project
10. The Netherlands: Ministry of Economic Affairs (EZ)

11. The Netherlands: Netherlands Agency for Aerospace Programmes (NIVR)
12. The Netherlands: National Aerospace Laboratory (NLR)
13. Poland: Ministry of Education and Science (MES)
14. Poland: Institute of Aviation (IL)
15. Portugal: Foundation for Science and Technology (FCT)
16. Romania: Romanian Space Agency (ROSA)
17. Slovakia: Ministry of Transport and Communications of Slovak Republic (MDPaT)
18. Slovakia: University of Zilina
19. Spain: Centre for the Development of Industrial Technology (CDTI)
20. Sweden: Swedish Agency for Innovation Systems (VINNOVA)
21. Switzerland: Innovation Promotion Agency (CTI)
22. United Kingdom: Department of Trade & Industry (DTI)

Associated partner: Eurocontrol (exit 2009)
Observer: European Research Establishments in Aeronautics (EREA - exit 30.06.2009)

Entries / Exits: new Hungary and Croatia, out: Czech Republic

- 2008: Entry of Hungary (National Office for Research and Technology (NORT)) and of National Centre for Research and Development (NCBiR/ Poland)
- 2008: Exit MES/ PL
- 2009: Exit of Czech partner, DPAC/France, NIVR/ NL, IL/ PL, CTI/ CH
- 2010: Croatia is about to step in; Entry of Secretariat for Education and Research (SER, CH) and of Technology Strategy Board (TSB/ UK)

This report is based on the following sources:

- Basic information from CORDIS
- Responses of coordinator and four participants to CRIMASS online survey (*status of 24 January 2011*).
- In-depth interviews with the coordinator and three partners
- No Beneficiaries answers available (no joint calls)

1.2 Critical Mass analysis

1.2.1 External factors and policy objectives related to Critical Mass

We understand "critical mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field.

According to what the interviewees indicated, the ERA-Net's objectives are:

- To address socio-technological challenge: also defined in ACARE's Strategic Research Agenda (SRA) – objectives are very precisely defined in measurable terms (reducing noise, CO2 emission, gas consomption etc, security), and are largely driving research in Europe (2: coordinator and 1 partner)
- To address a scientific challenge": Building aircrafts (3: coordinator and 2 partners)
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons": to maintain competitiveness towards USA (3: coordinator and 2 partners)
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (2)

- To reach excellence (2)
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (1)

It is clear from these answers, that the objectives of the ERA-Net are not at all clear to the participants. Type 2 ("scientific challenge") and type 3 ("defensive CM") are mentioned most often (3 times each), however there are also three other objectives mentioned at least by two (type 1 "socio-technological challenge", type 4 "prospective CM" and type 5 "excellence"). Reasons for this disagreement might be the very different national interests in this field, which have not been successfully mediated by the ERA-Net collaboration.

Secondly, the policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.
Trust building is central in the field. Aeronautics is peculiar, as the do have to collaborate not only at the research but also at the industrial level. For building aeroplanes, they are dependent on each other and competitors at the same time. They have a long-lasting international collaboration with respect to strategic research agendas. As a field of research, Aeronautics is rather mature. It is dominated by a few key actors in industry (Airbus, Rolls Royce, SNECMA, Thales, Finmeccanica, MTU, EADS) as well as research Centers (DLR, ONERA, CIRA). The research requires large physical infrastructures and this is available in the EU (the ERA-Net has done a description of infrastructures for future planning and prioritizing). It requires also geographical concentration, currently in Europe present in Toulouse, Hamburg, Munich.
World-leading in research field: USA, CAN, AUS i.e. no European country among top 3, in Europe DE, FR and UK are leading; but the EU as a whole is indicated by the coordinator to be leading (with the US being second).
Most obviously from these descriptions appear the following types of objectives:

- To address socio-technological challenge (one needs ideas on how to transport people in future using less and less energy, creating less air pollution and increasing safety more and more).
- "To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons": to maintain competitiveness towards USA.
- Alternatively, this last point would also support the view to see this as an issue of reaching excellence by pooling resources in order to compete with the US and others.

1.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give some indication on what kind of achievements can be expected. The progress with setting up Strategic Research Agendas clearly points to the CM objective of addressing a socio-technological challenge.

- Joint activities: no calls, just two open synchronised calls between DE and AT;
- HOWEVER: joint strategy building has literally been "invented" in this field, this has been done already using the instrument of European Technology Platforms: three Strategic research agendas, implemented by the ETP called ACARE (Advisory Council for Aeronautics

Research in Europe: ERA-Net members plus larger group of stakeholders who commit themselves to the strategic research agendas).[1]

1.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives an assessment on the achievements of the exercise.

Critical Mass of Funding budgets:

- Coverage of relevant countries: YES according to coordinator (GARTEUR makes already up the core, but with the enlargement of co-operation under the ERA-Net scheme, now all countries with a civil aeronautics research programme are on board, plus many more countries who wanted to join).; Most participants agree, only one says that Ukraine is missing, too (it has a big tradition in aviation acc. to them).
- The network (incl. ACARE, GARTEUR) is already a critical mass of excellent participants, made of big companies, SMEs, research centres and universities.
- No joint calls, only bilateral between DE and AT. Some countries clearly had the expectation of joint calls, but differences in programming have not been overcome. Some actors cannot commit enough resources for international cooperation.
- Bilateral DE-AT calls showed that duplication of research could be avoided and access to the European value chain was opened (for AT producers).

➔ Author's comment: Although DE and AT are positive about their collaboration, the network has failed to pool the national funding in a larger manner, because of very diverse national interests which have not been mediated.

Critical Mass of Researchers:

- No joint calls, only bilateral between DE and AT. Some countries clearly had the expectation of joint calls, but differences in programming have not been overcome.
- European countries together can be regarded as world-leading in the field (UK, DE and FR), each country alone is not competitive vis-à-vis the US, they need transnational European collaboration.
- With regard to the joint projects between Germany and Austria AT sees a very high academic quality. Also the economic opportunities arising from these research activities are supposed to be very favourable.
- With regard to new applicants AirTN has been somewhat successful. The ratio of new applicants (those that have not filed any requests with the Austrian FFG) was 40% last year.

[1] **European Technology Platforms (ETP)** have been introduced in 2002 as a means to realize the ambitious goals of the Lisbon agenda. ETPs should bring together stakeholders (e.g. regulatory bodies, industry, public authorities, research institutes and the academic community, the financial world and civil society) in areas of major industrial relevance for Europe. Their major role is seen in enhancing science-industry collaboration and in developing long-term R&D strategies which address **major technological challenges** (Strategic research agendas (SRA)). For the implementation activities of the SRAs, the ETPs are expected to raise private and public funding, meaning with respect to the latter that they are expected to influence public programming, in particular the priorities of the Framework Programme. **Joint Technology Initiatives (JTIs)** are a means to implement the SRAs of a limited number of ETPs. These few ETPs had achieved such an ambitious scale and scope that they required the mobilisation of high public and private investments as well as substantial research resources to implement important elements of their SRA. Based on these grounds, six ETPs have so far been identified to become JTIs (among them **Aeronautics – Clean Sky**).

➔ Author's comment: ERA-Net calls could be a means to maintain Europe's leading role in the field. Transnational projects can allow reaching critical mass in terms of number of participants and competences.

1.2.4 Critical Mass objective achievement

In this section, we report how respondents assess the achievement of objectives and, secondly, how the level of achievement can be judged based on output indicators.

The first aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

Answer from coordinator: With respect to all three objectives mentioned above, steps have been made forward. Also, participants, see some progress for some objectives. Some indications here are partly different from their initial answers (see 2.1), see the list below.

- To address socio-technological challenge (coordinator)
- To address scientific challenge (3, coordinator and 2 partners)
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (3, coordinator and 2 partners)
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (1 partner)
- To reach excellence (3 partners)
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (1 partner)

The picture remains that the participants have very different views on what the ERA-Net should have achieved. This is certainly different for those two countries who have had the bilateral calls (DE and AT), but it is also different, because the expectations and the underlying national interests have not been put on a common basis.

Secondly, we look at the list of output indicators as reported by the interviewees and survey respondents. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can now do a check which CM type is best supported by the output profiles given by the interviewees. There are discrepancies by the respondents, as can be seen in the table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-techn. Challenge	New processes, products and services; Access to new markets.	The most important indicators are witnessed / supposed, although one of them only by coordinator. Other, less important indicators mostly not witnessed.	
Address scientific challenge	Scientific publications, creation of access to new research fields	The most important indicators are witnessed / supposed, although one of them only by one participant. Less important indicator not witnessed	*In author's view less applicable than type 1 (socio-technological challenge), see section 2.1.*
Securing a	Scientific publications,	Almost all most important indicators	*No real agreement by respondents.*

level of competence (defensive)	improved processes etc., new research contracts.	witnessed, but only new research contracts by more than one respondent. Some less important indicators expected by coordinator.	
Securing a level of competence (prospective)	*Similar to defensive CM, but logically, it can only be one of them.*		
Reach Excellence	Scientific publications, improved position in international ranking, market share of the EU / world business sector.	Except for patents, most important indicators are witnessed / expected, but all of them only by one respondent each.	*No real agreement by respondents.*
Self-sustained dynamics	Scientific publications, additional researchers, networking, increasing number of actors active in the field	Except for patents, the most important indicators are witnessed / expected, two of them by more than one respondent. Most indicators of minor importance are witnessed by more than one respondent, too.	*In author's view less applicable as an objective of its own for this ERA-Net.*

Overall, addressing a socio-technological or scientific challenge and reaching self-sustained dynamics are more clearly supported according to indicators compared to other types. There is also evidence for reaching excellence or securing a level of competence, but here disagreement of respondents is higher.

According, to the author's assessment, most important among these objectives seems to be to address a socio-technological challenge, as it has been identified from the beginning at least by the coordinator and one participant, and it fits to the peculiarities of the field better than the objective to address a scientific challenge. Although this is a mature area, new actors have entered the field, which is explained by the coordinator as firms applying their technologies (established for other applications) now to aeronautics, e.g. in order to reduce the weight of aircrafts. This contributes in the end also to the socio-technological challenge of saving energy consumption. Therefore, the objective of reaching self-sustained dynamics seems to be less applicable, too.

Many other assessments appear less reliable, as they refer only to a small project base of bilateral DE-AT projects and respondents also disagree about whether they can be witnessed or not.

So, overall, while one can concede progress with respect to addressing socio-technological challenge, the other objective related to critical mass has not (yet) been realized: there is no real progress visible in securing a level of competence or reaching excellence as compared to the US.

1.2.5 Factors relevant for achievement or non-achievement

While we describe in section 2.1 possibly relevant environmental conditions and in section 2.2 possibly relevant determinants (activities), we arrive in sections 2.3 and 2.4 at the results and level of achievement. In this section we draw a first analytical conclusion from this case study about which of the above mentioned factors (either environmental conditions or something related to ERA-NET activities) appears to be a relevant factor for (non)achievement of CM. The statements are based on the indicators or other evidence from the interviews in this case study.

- **Field of research is very close to industrial application**: Here, mutual trust plays an enormous role. Common research always faces potential IPR conflicts and a very good governance needs to be established. All participants remarked positively that FP6 AirTN

contributed enormously to mutual trust building among this large set of participants and has created the base for collaboration.

- **Individual rationales / national interests going beyond learning or networking, but not for coordinator:**
  - Some members wanted to create transnational projects and open up their individual programmes.
  - Some others did and still do not want to invest in this ERA-Net initiative. There is a large difference between the scale and structure of national funds. It is not only a case of limited resources, but also of political willingness.
  - Coordinator, however, only wanted to network, did not see an individual need for closer collaboration.
- **Less engaged coordinator**:
  - It seems that the coordinators themselves did not see any extra value in the ERA-Net instrument and its objectives. They were happy with the level of international cooperation at the level of GARTEUR and ACARE which is mainly about building a common strategy.
  - Most participants regard the joint transnational activities as not so effective (the exchange of information and best practices, even if quite huge, did not result in any significant improvement of the national programmes).

1.3 Conclusions

It seems that the existing coordination structures in the field work well, in particular the Strategic Research Agendas by ACARE. This work clearly specifies socio-technological challenges, which need to be addressed. Perhaps, one has to acknowledge, that because of the closeness to industrial application, it is difficult cooperate internationally at the R&D level. Therefore, the platforms, which include also industrial stakeholders such as ACARE (see footnote above on ETPs and JTIs), serve perhaps better the needs of the field. However, regardless of type of instrument used, there is the wish of several participants to pool funding and other resources in order to implement the SRAs and this has not (yet) been achieved.

More generally, public R&D funding for Aeronautics is very different at national level. There are states with and there are ones without a specialised R&D programme. As the research field is very much linked to industry, mostly those states, which have strong industrial actors in this sector, offer also public funding for research. For reasons of competition, many states are moreover reluctant to pool resources at the European level. This makes a common approach more difficult.

With respect to leadership in the world, the field has been clearly characterized as being dominated by the US and other non-European actors. Combined knowledge and excellence of Europe (in particular of UK, FR and DE) can however be regarded as world-leading, i.e. also better than the US. Therefore, further activities at collective level make sense, which could be able to contribute to securing this level of competence.

2 The ERA-NET BONUS

2.1 Introduction

BONUS ERA-NET is a project under the EU 6th Framework. This project brought together the key research funding organisations from all the EU member states around the Baltic Sea as well as Russia. It is shaped as a consortium of 14 partners whose goal is to establish a network and partnership of key agencies funding research with the aim to deepen the understanding of conditions for science-based management of environmental issues in the Baltic Sea. BONUS ERA-NET operates in close connection with the scientific and management actors. BONUS ERA-NET workshops and meetings brought together marine research programme managers, science advisers, legal counsels and finance managers from the partner organisations. In addition, teaching professors in marine sciences, marine research infrastructure managers and scientists were invited to specific workshops.
BONUS made the national research funding organisations cooperate by building a Joint Baltic Sea Research Programme (called BONUS-169) to fund research. The aim was that the Joint Baltic Sea Research Programme would be implemented under Article 185 (formerly 169) of the Treaty of the European Community. The European Parliament approved this on 16 June 2010. But a first call (Bonus+call) had been launched in the meantime under the ERA-Net+ format on September 2007.

A special body fully dedicated to the implementation and management of the Article-185 has been set up, since a new dedicated legal structure was required : the BONUS EEIG (Bonus Baltic Organisations Network for Funding Science EEIG). The Secretariat of BONUS EEIG was established in Helsinki and, in addition to running the everyday administration of BONUS EEIG, the Secretariat also took care of the coordination of BONUS ERA-NET until the end of 2008 and manages the BONUS-169 Joint Baltic Sea Research Programme. First countries to join were Finland, Sweden, Denmark, Lithuania and Estonia, which were soon followed by Poland and Latvia. Germany joined in December 2007. Negotiations with Russia are ongoing. Only funding agencies can be formerly members, and others are associated. BONUS EEIG is funded by the member fees and the Finnish Ministry of Education.

Research Fields: Marine Science, Environment (including climate change), Food, agriculture and fisheries, Government and social relations, Socio-economics sciences and humanities.
Sector : Environment
Other ERA-Nets in related fields: AMPERA, MARIFISH, MARINERA, IWRM.Net-CA; SEAS-ERA in FP7
Type of research: Basic and Applied research
Duration:
BONUS (BONUS for the Baltic Sea Science – Network of Funding Agencies)
5 years in FP6: Dec. 2003 – Dec. 2008
BONUS+ (Call for research projects within the Joint Baltic Sea Research Programme)
5 years in FP7: May 2007 - May 2012
EC funding: BONUS : €3 029 453 (FP6, Source: CORDIS); BONUS+ : €7 266 762 (FP7, Source: CORDIS)

14 partners : 12 from 7 countries and 2 international organizations in Bonus :
Coordinator: Academy of Finland in 2003-2007 and BONUS EEIG Secretariat in 2008

Partners:
•Forschungszentrum Jülich – Projektträger Jülich, Germany
•Danish Agency for Science, Technology and Innovation (Danish Natural Science Research Council), Denmark
•Estonian Science Foundation, Estonia
•Ministry of Education and Science of the Republic of Lithuania, Lithuania
•Latvian Council of Science, Latvia
•Ministry of Science and Higher Education, Poland
•The Foundation for Strategic Environmental Research , Sweden
•The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden
•Swedish Environmental Protection Agency, Sweden
•Russian Foundation for Basic Research, Russia
•Institute of Oceanology, Polish Academy of Sciences, Poland
•International Council for the Exploration of the Sea, international
•Baltic Organisations Network for Funding Science EEIG, international

6 observers were also associated, 5 from 4 countries and 1 international organization :
Deutsche Bundestiftung Umwelt, Germany
Deutsche Forschungsgemeinschaft, Germany
Estonian Ministry of Environment, Estiona
Latvian Environment Agency, Latvia
Maj and Tor Nessling Foundation, Finland
Nordic Council of Ministers: Marine and air pollution group, international

Entries / Exits: Changes in the partners occured when the BONUS EEIG was created; when comparing the composition of the BONUS and BONUS EEIG these changes are the following:
Entry:
• FiRD Coop (Academy of Finland) (Finland)
• Latvian Academy of Sciences
• Research Council of Lithuania
• Foundation for the Development of Gdańsk University (Poland)
• National Centre for Research and Development (NCBiR) (Poland)
Exit:
•Ministry of Education and Science of the Republic of Lithuania, Lithuania
•Latvian Council of Science, Latvia
•Ministry of Science and Higher Education, Poland
•The Foundation for Strategic Environmental Research , Sweden
•Russian Foundation for Basic Research, Russia
•Institute of Oceanology, Polish Academy of Sciences, Poland
•International Council for the Exploration of the Sea, international
•Baltic Organisations Network for Funding Science EEIG, international

BONUS EEIG does not mention explicitely the association of observers.

But it must be stressed that most of these changes are only reflecting an internal reallocation of tasks within participating countries in order to comply with the EEIG rules or because of reorganisation/renaming in the national research systems; the only exception is the Russia, whose participation to BONUS EEIG is still under discussion.

This report is based on the following sources:

- Basic information from CORDIS
- Information from the BONUS website
- Responses of coordinator and two participants to CRIMASS online survey (*status of 31 January 2011*).
- In-depth interviews with the coordinator (BONUS EEIG, international) and the following partners: Marine Systems Institute acting for the Estionan Science Foundation (Estonia), Danish Agency for Science, Technology and Innovation (Denmark), Swedish Environmental Protection Agency (Sweden) and Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Sweden).
- 134 Beneficiaries identified (ie participation to a project), contacted for the S2 survey.

2.2 Critical Mass analysis

2.2.1 External factors and policy objectives related to Critical Mass

In order to understand the rationales underlying the set up of BONUS as well as its organization characteristics, it is useful to bear in mind the environmental characteristics of the research field. From e-surevy and interviews, it is possible to briefly summarized them as follow.

The area of research related to BONUS is :
- already partly explored but with a lot of research going on and an increasing number of researchers/labs involved
- investigated by a lot of competing actors with no clear leader
- internationaly wide, leading countries in research are USA, UK, Norway, Germany; USA is considered a bit ahead of EU
- is partly dependant on large physical Infrastructure only available in one or a very few places, and available in Europe
- is not essentially requiring some local concentration of actors (academic-agencies-companies) around localized research infrastructure and close face-to-face interactions favoured by geographic proximity
- is so far relatively independent from the developments in other research areas
- is backed up by international organisations notably offering data and products services, such as EuroGOOS, the European Global Ocean Observing System (member agencies of EuroGOOS offer a large variety of operational oceanographic products, both for the national coasts of their countries and for larger sea areas, products include nowcasts/forecasts, oceanographic databases, and bathymetric maps) or EMODNET (European Marine Observation and Data Network)
- is connected to future and foreseeable market

More broadly, the first main characteristic of research in the BONUS area is that it is very dispersed among different fields, disciplines and different scientific cultures. Notably, marine research and maritime research are often distinct; within the marine field, essentially at stake in

the case of BONUS, the lead is taken by biologist at some point in time, or by physical oceanographers at some other point. To some extent, each country has also some fields of specialization. These areas of research are also often corresponding to different public programmes and public agencies/ministries.). It is then very difficult to map the research in marine field, the landscape being very sketchy with a lot of small teams.

A second important characteristic is that a large part of the activities are "knowledge-based" ones but not identified as research per se : these are data acquisition, storing and treatments, and field monitoring. This is done with a lot of various experimental devices, including vessels and probes etc. This is common to all marine and maritime activities, from fishering to research on sea bottom (coast, minerals, pipelines, wind farms, fish farms etc); and there are often possibilities of synergies between these activities at this level.
Correspondingly to the previous point, there is also an issue of Research Infrastructures (in particular vessels and instrumentations, but also advanced computing facilities), which are key, but are not located in a single location, are mobile, are costly in terms of functionning and maintenance, and are subject to fatigue and wear and with rapidly evolving technologies.

At international and institutional level, there were a lot of differences across countries regarding the existence of programmes on Baltic fields, but also discussions about what is to be considered as a programme. Sweden and Finland shared the same views on what is a programme (calls, project, time limits etc); in Balt countries, there was no programmes (but there was research here and there); in DK research was funded on the basis of the definition of broad topics with corresponding agencies; in Poland, there was programme but highly top-down structured; in Germany, the funding was much more on a continuous basis over long period. At the begining, it was understod that EC wanted ERA-Net to be set up on the basis of existing/established programmes at national or regional levels, ERA-Net "adding" a layer on the top of that or facilitating coordination between them. But in the case of BONUS, it was difficult since marine and maritime were dispersed, and some countries did not have programmes exactly corresponding to BONUS.

From the elements mentionned above, it is clear that there was a key need of bringing actors together at research level as well as at public policy/programme level. More specifically, the main policy rationales and objectives aimed at by setting up BONUS are described below.

a. BONUS : initially a research based initiative

The story started in 1999, apparently when Academy of Science of Finland established group of research and set up Finnish programmes in the field, but more broadly scoped. Contacts were established with other countries researchers, especially with Sweden and Germany and also with programmes supported by the World Bank etc. In each country (at least those that were at the start of the process), individual researchers were convincing the research community and then the policy level. It rapidly appeared that the ERA-net could be "the" instrument to set up. In general, BONUS has been largely influenced by scientists who are very present at all levels of decision.

b. The specific environment of Baltic

At a very first stage, the idea was to set up an ERA-Net covering all seas in relation to EC countries. But it became rapidly clear for the Baltic countries that the scale was too broad, given the

numbers of countries concerned with marine research, and especially given the specificities of regional ares/sea basins (shore side, environmental conditions and stress, economics, internal biodynamics, etc). In particular, Baltic sea has a very low salinity with low oxygen presence, it is almost closed so the path of renewal of water is very slow (30 years, as Mediterranean sea, but with less deep water/surface water exchanges in the case of Baltic sea), few ocean fish species, etc. These conditions are quite homegenous for all Baltic and then for all countries, despite some local specificities, which plaid for the inclusion of all of them in BONUS.

c. A pre-existing background of cooperation between Baltic countries

There were cooperations in the field of BONUS between Baltic countries long before BONUS, beyond the initial "core" of BONUS initiators, but not intensively with the former Eastern countries. For instance there is the Helcom (or Helsinki Commission, working to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between all baltic countries, and being the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention, see http://www.helcom.fi/helcom/en_GB/aboutus/). Or there were joint experiment campaigns in the 70s or 80s (ex in the 70s an open research experiment associating 14 research vessels working 2 weeks together).

Generally speaking, cooperation between Nordic countries is also quite strong, from the Nordic Energy Research, a funding institution for energy research under the Nordic Council of Ministers – an intergovernmental body between Sweden, Denmark, Finland, Norway and Iceland, to energy field, through Interreg. When Finland and then Germany had the EU presidency, they launched the "northern dimension thinking" centered on the Baltic Sea. There is also a Top research initiative in climate field between the Nordic countries. And there were also bilateral initiatives (for instance about researchers and students mobility, which was also supported by the Nordic Council of Baltic countries).

d. BONUS is coherent with a larger policy trend

A important aspect is that BONUS (and later development through Bonus+ and Bonus-169) comes in an "institutional environmental" in which a lot of global policies and strategies have been launched at European level in the very broad area of "water", some by the DG Environment, some by the DG Research, some by the DG Marine (Water Framework Directive, Marine Strategy Framework Directive, Strategy for the Baltic Region, Maritime Policy, Common Fisheries Policy, Roadmap for Maritime Spatial Planning, Marine and Maritime Research Strategy…). Clearly, BONUS is part of a larger trend (reinforced in the EC Strategy for Marine and Maritime Research[2]) aiming at bringing different disciplines and sub-disciplines working together, which was not sufficiently done in the past, and which is absolutely required for achieving the objective of using in a sustainable way the oceans and seas.

[2] A European Strategy for Marine and Maritime Research A coherent European Research Area framework in support of a sustainable use of oceans and seas, COM(2008) 534 final; see http://ec.europa.eu/research/mmrs/documents/documents_en.htm#opt1

There is also a relation with the EU Baltic Strategy launched as macro-regional strategy in 2009 by DG Regio, under the initiative of the European Parliament/Baltic intergroup[3]. No new money is planned, but more coordination.
The justification of BONUS has finally to do with the working of Helcom (see above). Helcom needs to take decision on the basis of scientific arguments; but if one country proposes something only on the basis of what "its" scientists are advocating, it is not easily accepted. So if all scientists from all countries can agree on saying something on one specific subject, it has much more power and influence. Then BONUS can play a role in that, by facilitating the set up of such common position from the scientists.
A lot of points raised and of objectives set up in all those initiatives are clearly related to BONUS, and BONUS was even cited different times in some of the background documents, for instance in the action plan following the Baltic strategy, although nobody ever approached BONUS. But generally speaking, the problem is that those initiatives are not very well connected, especially when implemented at national level (there are some inter-service groups at EC levels however, but generally speaking EC Directorate are quite compartmentalized). BONUS was a way to contribute to connect them at research level, but also a a supplier of analysis, data, diagnosis and scientific expertise.

e. A link to former Eastern countries

In general, the research was very strong in the four leading countries (Finland, Sweden, Denmark and Germany). There was a national programme in each of them , but they felt the need to work closely together, in order to have global treatement, global data, global models etc. As said, there were already contacts and cooperation between them, for instance at research level through Helcom (in fisheries, but limited to Nordic countries), or through Interreg programme that allowed to associate Germany. But there was a need to bring in the Eastern countries, in order to have a complete coverage of the Baltic sea, especially as regards pollution and environmental issues.
For cooperation with USSR and its satellites, at the level of scientists, there were as early as in the 60s some scientific organisations (such as the Baltic marine biologists) linking researchers and organizing conferences every two years. At higher / country level, Helcom was set up in 74, without the Eastern countries at the begining, but in 1992 there was a new agreement and they got into Helcom. So at both levels (science and policy) there was a basis for further cooperation.
So when EN was launched, it was seen as an opportunity to use this instrument to develop further on the collaboration, and also to get Eastern research on board and open access to Eastern researchers, data and works. ERA-Net was considered as a convenient way to do so, because of its "regional character", of the participation of national agencies, and the smaller size of projects are compared to a lot of the classical EC ones (so it was seen as a good "first step" to involve those countries).

2. Consequences in terms of critical mass related objectives

[3] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS concerning the European Union Strategy for the Baltic Sea Region, COM(2009) 248 final; see http://ec.europa.eu/regional_policy/cooperation/baltic/

It is clear from what preceeds that “to address socio-technological challenge" is the main critical mass related objective. The general objective is to deepen the understanding of conditions for science-based management of environmental issues in the Baltic Sea. So it is clearly research oriented, but for social long term purposes. But "to reach a self-sustained dynamics" appears to be also important.
This is confirmed by the interviews and by the e-survey.

- “to address socio-technological challenge" (cited by all interviewees and by 2 respondants): key issue; the challenge requires to develop new ways of science and policy interfaces, and interdisciplinary interfaces in order to value eco-system (including taking into account economic consequences) and help policy-making; the "scientific challenge" aspect of this critical mass is related to the interdisciplinarity (before, marine research was a domain as such). So challenges are also in terms of organisation, and not only in the research content/output
- “to secure a certain level of competences” (cited by one interviewee) : in this case it is rather in a "quite traditional area" and to some extent, because a large share of the research institutes involved have a dual activities : research but also responsability of monitoring and of maintaining monitoring capabilities and functions (storm, waves, etc). To integrate both aspects is important
- “to reach excellence” (cited by one respondant) : not as such, only a few project are really involving World Top level research, but it is not what is aimed at; however, all projects are high levels ones from a scientific point of view
- “to reach self-sustained dynamics in the development of the area” (cited by 3 interviewees and one respondant): very important as well. This is confirmed by another set of answers to the e-survey in which "Networking and building new relationships with funders from other countries" was the most cited general objective of BONUS, followed by “creating and supporting transnational projects in a field which requires transnational cooperation”, testified by the develoment in Bonus+.

2.2.2 Determinants of Critical Mass

The determinants of the critical mass are the participants, the activities that have been conducted during the ERA-Net, the way those participants were interacting and conducting these activities, all this deterining the conditions in which resources are pooled together and possibly reach a critical mass level.

Countries and participants

They have been listed in the introduction. As usual, there is a mix of actors such as ministerial services, agencies and councils, fulfilling the roles of programmes owners, programmes managers, programmes funders; but there are often some research operators or individual researchers acting under delegation of actors to play some of these roles, or acting as advisers. It has not been that easy to get the funding agencies, but the "countries core group" and especially the coordinator were very active. Then in the FP6, only information exchanges, coordination, strategic activities took place.
It appears that all countries neighbouring the Baltic seas are involved. And in general, most of the potential participants are also involved either in BONUS or in BONUS+ or in BONUS EEIG. Only a few basic research agencies may be seen as missing, in Sweden and Germany in particular.

Activities

As regards activities, BONUS, BONUS+ and BONUS-169 (article 185) are really showing a coherent evolution. BONUS paved the way to the next phases, with workshops and meetings bringing together managers of marine research programmes, science advisers, legal counsels and finance managers from the partner organisations. In addition, teaching professors of marine sciences, marine research infrastructure managers and scientists were invited to specific workshops. BONUS ERA-NET did not offer funding for networking of scientists or research projects. Instead, it made the national research funding organisations cooperate by building up a Joint Baltic Sea Research Programme (called BONUS-169) to fund research and be implemented under Article 185 (approved on 16 June 2010). But a first call (BONUS+call) had been launched in the meantime, within the framework of the BONUS-169 Science Plan (prepared under the ERA-Net BONUS, and the basis for the design of BONUS-169 in itself) on September 2007.

To sum up :

- BONUS ERA-Net (2004-2008) consisted in developing pre-conditions for a Joint Baltic Sea Research Programmes, ie a lot of non-RD activities preparatory activities had been carried out in ERA-Net. Among them were in particular an inventory of marine research infrastructures, a mapping of the ongoing projects, the elaboration of the BONUS-169 Science Plan and Implementation Strategy which has been used a as guideline in planning the content of first BONUS+ Call and the Joint Baltic Sea Research Programme, a proposal for common use of infrastructure, the creation a postgraduate training scheme for Baltic Sea studies, a census and bibliometric analysis of publications in the field of Baltic research.
- BONUS+ (ERA-Net+, 2007-2011) essentially consisted in the implementation of a joint call (BONUS+call) to test the mechanisms of collaboration among the national funding institutions, and of course launch "real" projects (see below).
- Now in the BONUS-169, runned under the Art185 framework (2010-2016), there is a first Strategic phase (2010-2011), preparatory to the Implementation phase (2012-2016) in which at least 3 calls will be launched (one per year, given that these are normally 3 years projects, and that the projects should stay in the limit of the Art185 time frame, ie finishing end 2016). In the Strategic Phase, different activities are to be mentionned :
    - The BONUS Poll on Priority Research Topics in Baltic Sea System Science - Community of scientists and other stakeholders, more than 200 propositons were collected
    - The BONUS Forum of Sector Research Kick-off Conference (oct 2010, 66 participants) - grouping Ministries of the Baltic Sea countries (transport, energy, environment etc), funding organisations, scientists in order to collect research needs; it is expected that this forum will be held yearly and be more open than the kick-off one, and it will be the opportunity to show the results of projects
    - the Creation of the group of "BONUS advocates", national representative appointed by BONUS in order to identify appropriate stakeholders, to do some "lobby" activities and to organize workshop and events at National level; some advocates are coming from BONUS community, some other not; they are very active and will report in January 2011.

Then the final Strategic Research Agenda, agreed by research policy, science community and stakeholders will be based on the results from the previous activities, and is to be issued in March 2011 at the Strategic Orientation Workshop (SOW). 5 research areas are already emerging, with also some "horizontal issues"; however, some "cross-sections" between areas and issues are already covered by existing programmes, and BONUS-169 will try to address those not already

covered.
Nowadays, another initiative has been launched aiming at atracting the "innovation side", and at first the funding agencies. An important meeting took place on december 16 2010. It is argued notably that innovation can be complementary since it comes at another point of the project life-cycle (BONUS being more upstream). It is argued also that BONUS has science, research subjects, money (EU part) and innovation agencies may develop plateforms in line with the Baltic EC strategy (see above). It is required to develop instrumentations allowing to get good data, good monitoring, good models etc on the one hand, but also to develop solutions for achieving a "sustainable management of Baltic sea" once scientific questions are answered. Innovation is then the "missing link" between science and social needs in that respect. One important additional reason is that BONUS-169 is looking for money : presently, the total funding for years 2010-2016 is 100 M€, with EC funding up to 50M€, matching national contributions; national contributions up to now are 12M€ that could be reported as joint use of research infrastructure, 26 M€ committed by BONUS members in 2008, that means that 12 M€ additional fundings are needed for the mobilization of the maximum EC fundings. The point is that there are a lot of of actors, agencies, ministries etc active on the innovation side or the marine and maritime sectors, even more than on the research side. This orientation is apparently agreed by a lot of BONUS partners, although some worry a bit, and this will be sorted out and decided in the next March 2011 meeting of BONUS (ie decide to which extent involved the innovation side); possibly at least shipping and maritime areas will be approached, with good potential examples to be found in ICT. Top innovators are targeted, and it is assumed that in the corresponding fields, there are a lot in the Baltic countries.

The BONUS+ call

The focus was clearly on research supporting an ecosystem-based approach to management of human activities. It should enhance our understanding and predictive capacity about the Baltic Sea ecosystem's response to impending changes caused by both naturally and human-induced pressures and about linkages between environmental problems and the social and economic dynamics in responding to them. In turn, the research should support formation of the basis for prudent management aimed at safeguarding the sustainable use of the ecosystem's goods and services.
The proposals should focus on key research issues described in the BONUS – 169 Science Plan:
Theme 1: Linking Science and Policy
Theme 2: Understanding Climate Change and Geophysical Forcing
Theme 3: Combating Eutrophication
Theme 4: Achieving Sustainable Fisheries
Theme 5: Protecting Biodiversity
Theme 6: Preventing Pollution
Theme 7: Integrating Ecosystem and Society
In the evaluation process, priority will be given to research projects within Themes 1 and/or 7 and to projects that link Themes 2–6 with 1 and 7 in an interdisciplinary manner. However, interdisciplinary research among Themes 2–6 is also encouraged.

Total amount of funding by BONUS EEIG for this call is 22.4 M€, consisting of allocations by national funding agencies (2/3) and FP7 ERA-NET+ funding by the European Commission (1/3).

The deadline for BONUS+ Letters of Intent was December 2007.
The BONUS EEIG Secretariat received altogether 149 Letters of Intent from 19 different countries. The total of applied funding amounted to ca. 189 M€ from 928 different participants. All eligible Letters of Intent were evaluated by independent experts. Based on the ratings and comments given by the evaluators, the BONUS EEIG Steering Committee decided in its meeting on 12 March 2008, to invite 55 of the proposers to submit a Full Proposal.
The deadline for submitting the Full Proposals was April 2008. All 55 invited proposers submitted their Full Proposal, the total applied funding being over 81 M€. All the Full Proposals were sent for evaluation to an International Panel.
Based on the evaluation of the scientific excellence, quality of implementation, foreseen impact and relevance of the project to the management of the Baltic Sea, altogether 16 projects (success rate 10.7%) were decided to be funded, including 134 Beneficiaries identified (ie participation to a project).

Generally speaking, interviews and e-survey converge in considering a good or high level of coherence between all BONUS activities, with a clear continuity between ERA-Net, ERA-Net+ and art 185. However, depending on the participants, the interest and the use of some of the BONUS outputs may vary (for instance survey on research activities and programmes was interesting, but used in a very limited way for some, while for others the specific study performed using these data, with bibliometrics and other type of deep analysis, was highly useful. For most of all, the most interesting was the process of the call, including all stages (evaluation, monitoring, using experts advise, solving problems etc); it really allowed to compare ways of doing things. At the end, it is not so different from what is usually implemented at national level, but at bigger and international scale.

Overlap with other ERA-Nets:
According to the interviewees, there is not much overlaps between BONUS and other ERA-Net. Although, there are relations with other ERA-Net in the field. But generally speaking, BONUS chooses to be observer because most of the time BONUS was a bit ahead of these ERA-Net in terms of actions and achievements (ex SEAS-ERA in FP7, or AMPERA, MARIFISH were cited).

ERA-Net activities and national /regional programmes:
In terms of research programming and content, each country is a specific case, however in general, it seems that the complementarity is fairly high, and that countries are and will be avoiding overlaps with BONUS research. For some countries, there is a clear strategy to avoid any overlap with BONUS. BONUS was ahead in terms of mixing fields of research and promoting cooperation; in addition BONUS is addressing issues than are common to all Baltic countries, and that can be addressed with more means than those available for such countries. Then BONUS "is first", and the ministries/agencies are adapting the research agenda and funding allocation taking BONUS into consideration, and there is no programmes launched in the field covered by BONUS. But of course, such countries are launching in parallel other programs in the same field, for matters that are more specific to the national case. Sometimes, BONUS is explictely taken into account when defining strategic planning, with choices made in terms between national and BONUS ways channeling the fundings; clearly BONUS is a significant part of the country effort in Baltic research, and if money is already allocated for Baltic research in BONUS by an organisation, there could not be extra money for research in the same field under national or in the future

under another tool such as JPI. For such organisation, the support to international activities is at the highest level of the strategy, especially if it concern Helcom, Baltic Strategy and Marine Directive; then BONUS is exactly at the crossing of the efforts along those three axes. In other cases, BONUS activities are related to the activities funded under a precise line of budget, with set aside specifically for it, but there is not a real workshare between national programmes and BONUS that would be reflected in the budget allocation. BONUS is really very specific research. In other more specific case again, there is apparently no strong connection between national and BONUS activities in terms of research strategic agenda setting; the only real connection is through the call and the money that comes from the agencies.

In terms of fundings, it is highly difficult to assess what is the share of public funding for national programmes as compared to BONUS, not only because of the diversity of national situation (ie either regarding the size of the research expenditures and regarding the classification of research fields over which these expenditures are distributed), but also because of the diversity of fields covered by BONUS. In addition, the fundings may come from different national sources, increasing the complexity of the funding structure.

In terms of complexity of programme management and of administrative procedures, from BONUS point of view, BONUS is far much complex, because of the "mixed mode" adopted (common and virtual). Since money was given by EC to it, BONUS EEIG had to manage separately the two groups of countries, but endorsing the responsability of monitoring and auditing from EC point of view. This will be in principle simplified with the art185 rules : one single rule for all, but probably even more strict control and audit.

From national agencies point of view, the main issue was about some administrative problems related to specific points such as the differences in overhead rating, calculation and last minute changes, the mixed mode of fundings, and the legal possibility for some countries to delegate to a non-national body (ie BONUS) the right to decide how/to who their public funds will be allocated. This and the international dimension of the activities make the programme a bit more complex to manage in general.

From the beneficiaries point of view also, it is in general much more complicated than a standard national programmes, since some had to report to two agencies (national and foreign).

2.2.3 Components of Critical Mass

The components of the critical mass are the resources (in terms of quantity and quality) pooled for research by the beneficiaries in the context of the projects that are selected. It is not possible to have detailed information on the resources as such, therefore beneficiaries and projects characteristics are used as proxy.

Number of projects : 16
Number of beneficiaries (ie participations) : 134 identified
Number of beneficiaries (ie organisations): approx 100
Average number of beneficaries (ie participations) per project : 8
Average BONUS budget per project : 1 406 480 €
Average duration of project : 36 months
Nature of beneficiaries : almost exclusively university labs / research organisation labs (less than 5 companies identified)

In general, **projects** are considered as pretty much comparabe to EU projects in terms of risk, quality, etc (but only with 2 nationalities at least). Comparing to national project is difficult; for instance for one given country, projects are considered as larger than the ones usually funded by one agency, while considered as of standard size by another agency. Also, in quite large projects such as the BONUS ones, it is possible to have some aspects (for instance some WP) more risky than others, in small projects, the entire activity is at the same level of risk.
To note, more interdisciplinarity is required than in national projects. But there is no real specificities of the projects from an organisational point of view.

To some extent, some new **beneficiaries** are entering, but it depends on the country. Social scientist are more involved, notably via specific projects that are more related to this discipline (governance related). Before, there were probably reluctant to be associated with Natural science projects on Baltic because they were "a small one lost among the natural scientists" in the national / standard projects in the BONUS field. Now through BONUS, they have contacts with the other few social scientist working on BONUS themes in social sciences in the other countries. BONUS clearly allows to start to link them. This is especially the case for environmental economists and international politicy specialists. 4 out of the 16 projects are oriented towards science-policy relations. BONUS wants to support original and inter-disciplinary projects, then traditional proposal failed. For instance, proposing to improve an existing models was rejected, even this is a very good model. Even the proposal of top specialists were rejected on that basis. Another example is a project, proposed by a physical oceanographer, that aimed to mix modeling standard data and data from fishering industries to find optimal fishering area where pollution is minimal, and then optimize fishering vessels routes accordingly; this was accepted.

2.2.4 Critical Mass objective achievement

• The **profile of activities** runned by the ERA-Net gives a first indication of the achievement of the critical mass objective. The succession of activity, the progressive orientation of the activities (notably expressed by the BONUS-169 Science Plan and Implementation Strategy, the Joint Baltic Sea Research Programme and the Strategic research Agenda to be defined soon) and the topics reatined and projects selected in the BONUS+ clearly point the progress towards the CM objective of addressing socio-technological challenges, but also the attempt to trigger a self-sustained dynamics in the development of the area, by mobilizing more and more actors.

• As regards **outputs and impacts**, direct answers from interviewees, as well as information from e-survey and first projects reports bring some further elements, but also show that research activity as such is too recently launched to really ascertain the achievement of all dimension of critical mass objectives.

- In general, the projects have started too recently (and with a little delay due to administrative problems) for having generated a lot of Science & Technology outputs yet. However, there are already some, and publications is the first type of outputs cited.
However, all interviewees and respondants testify that network effects are undoubtedly arising, and are the most important effects at this stage. Not that the researchers did know each other before BONUS; but BONUS most probably reinforced the cooperation on the one hand, and most of all, open the cooperation to formely eastern countries, and this is probably the main point here.

In some countries also, BONUS allows to reinforce cooperation between the "domestic" researchers.
Logically, the emphasis has been on establishing the consortia, and gathering the initial data – both from the field and by experiments, data mining, contingent queries, and initial model runs.
In certain contrast to the FP programmes, BONUS has from the very beginning achieved a lively collaboration among the various projects through forming the free-geometry clusters to approach specific research issues, cooperative usage of sophisticated and expensive research infrastructures (e.g. research ship time and advanced computing facilities). In 2009, altogether 25 research cruises in the Baltic, five of them manned by the researchers of two or more BONUS+ projects have been undertaken. Still, according, to rather incomplete information, projects already received at least 778 kEUR in-kind contribution from other national sources in terms of access to the shiptime, and at least 400 kEUR contribution enabling access to the advanced computing facilities.

- Private exploitable returns: it is definitively too early; in addition, the potential of generation of such outputs largely depends on the nature of projects. But it is expected that new projects launched in the future calls will have a higher potential on this respect, since they are suposed to be more oriented towards innovation. Networking is here also the most cited effects.

- There is no large social returns yet, but there might be some in the future; the creation and access to new research fields (especialy interdisciplinary) is cited. But it is especially through the interactions science-policy, the providing of data, indicators expertise, and the policy making that could derive from it. A distinctive feature of the BONUS+ projects is their clear inclination towards practically useful outcomes that will qualitatively advance the whole system of the Baltic Sea protection policy and the collective effort to make its resources sustainable. Projects have commenced an active teaching activity, as well as a stake-holder work and dissemination from the very beginning of their implementation, from PhD course to advise and expertise to EC or other organizations, including workshops for scientific journalists.
One of the main impact is then the relation with Helcom, and the possibility for BONUS to support Helcom policy decision. It could be quite direct (for instance in relation to a BONUS project), but also more indirect : for instance when an issue comes to the place during the Helcom meeting, then the participating ministries are asking advice to the national scientists, who then will correspond with their counterparts on other countries, in part through the BONUS chanell or on the basis of the link created / developed thanks to BONUS. BONUS is then really supporting Helcom, to some extent it represents Baltic countries scientific community at Helcom. And there should be more benefits on this regards in the future, with the completion of projects and the launch of new ones.
Another important impact will be on the design of environmental policy, and especially the regulations. The environmental regulations are not changing every day, but there may be some windows of opportunity for adapting or changing some of them in the areas corresponding to BONUS. Contacts with law makers have already started. For instance, since the end 80s, there is a regulation for decreasing by 50% the nitrogen and phosphorus in all sea basins; now it becomes clear that this quantified objective has to be adapted to regional specificities, and in the case of Baltic, BONUS contributes to improve the scientific knowledge required to determine a more adequate objective. Other examples are in fisheries.
Another example is the emerging field of spatial planning : the mutiplication of "uses" and activities in the sea basin makes indispensable some sort of planning to allocate areas, eg for

deep-water mining, telecom cables fixing, wind farms, fish farming, fishing areas, recreation areas, rare natural species protection areas etc. There are examples now given by Australia coastal planning - coral protection, tourism, etc. This area of spatial planning may be addressed by a coming BONUS art 185 call.

The following account gives some highlights of the project implementation picked from the first annual reports.

Number of training programmes, workshop or diffusion events: 13, by 9 projects for 195 students
Number of times Projects have contributed to consultations carried out by European Commission: 7
Number of times the scientists working in the Projects have served as members or observers in stakeholder and scientific committees: 147
Number of times the effort of the Projects has resulted in modifications made to relevant policy documents and action plans (in particular, Baltic Sea Action Plan): 10
Number of suggestions for designing, implementing and evaluating the efficacy of pertinent public policies and governance originating from the work of the Projects: 49
Number of persons and working days spent by foreign scientists on research vessels participating in the cruises arranged by the Projects: 61 p, 748 days
Number of persons and working days spent by foreign scientists using other major facilities involved in the Projects:36 p, 482 days
Number of popular science papers produced by the Projects: 38
Number of interviews to media given by members of the Projects' consortium: 143
Number of multi-media products and TV episodes produced by the Projects with dissemination purpose: 9
Number of other dissemination products produced by the Projects.: 80
Number of times Projects teams have issued a recommendation how to improve general public's comprehension and priorities regarding the Baltic Sea: 26
Number of times the projects have contributed to dissemination products/events addressed to general public concerning coupling between marine environmental quality and human health and well-being: 67
Number of datasets the projects have delivered to the common metadata base of the Programme: 14
Number of scientists that attended international workshops, WG meetings, conferences, intercalibration exercises etc. paid by BONUS+: 308
Number of PhD courses organized by the Projects and persons participating: 11 c, 115 pe
Number of modifications made to current PhD course programmes that resulted from the work of the Projects: 11
Number of student visits (persons, visit days) from the Projects to other BONUS projects: 14 p, 122 days

In addition, impact on national agencies could also be noted. For some participants, BONUS was one if not the first ERA-Net, then they learn from it in many respects and this was used as an exemple / template for further EN. BONUS had an impact on how the participants see the programmes and about defining a common terminology as regards programmes setting, monitoring, evaluation etc. But formally, comparing different funding systems and procedures did not cause a lot of changes in national programmes, because there is a lot of inertia and things could not be changed overnights. But in details it helped (for instance as regards the yearly economic report) and it brought a more comprehensive knowledge background.
Mutual learning about the design of joint activities between programme owners and programme managers, thus enabling transnational R&D cooperation creating a forum for discussing R&D policy and priorities in specific research fields at European level
Preparation ot Art185 in particular was an important output from the BONUS+call, it helped a lot to understand the difficulty and complexity. This is always underestimated either by national

authorities and by EC. It would have been very dangerous to start with the Art185 at the beginning, without this (sometimes painful) experience.

Summing up the insights from interviews and survey is exhibted in Table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-techn. Challenge	New processes, products and services; Access to new markets.	The most important indicators are witnessed / supposed. Other, less important indicators mostly not witnessed.	
Address scientific challenge	Scientific publications, creation of access to new research fields	The most important indicators are witnessed / supposed. Less important indicator not witnessed	*In author's view less applicable than type 1 (socio-technological challenge) and in some sub-fields, seen as a first step towards the ultimate type 1 objective*
Securing a level of competence (defensive)	Scientific publications, improved processes etc., new research contracts.	Some important as well as less important indicators witnessed	*No real agreement by respondents.*
Securing a level of competence (prospective)	*Similar to defensive CM, but logically, it can only be one of them, although there is some specificic case (data monitoring) that may be seen as "in-between"*		
Reach Excellence	Scientific publications, improved position in international ranking, market share of the EU / world business sector.	Except for scientific publications, no important indicators are witnessed / expected	*Quite clear agreements between respondents*
Self-sustained dynamics	Scientific publications, additional researchers, networking, increasing number of actors active in the field	Except for patents, the most important indicators are witnessed / expected. Most indicators of minor importance are witnessed	*In author's view, a step towards objective type 1*

From these elements, some first conclusions can be drawn as regards the achievement of objectives related to critical mass.

- "to address socio-technological or scientific challenge" are quite clearly the key ones.

The measurement should be based on the comparison between the challenge itself and what has been achieved. The measurement will then depend on the nature of this objective. In case the objective is closer to a technological one or if it encompasses a social dimension, the measurement is to be based on more applied oriented outputs, on commercial oriented outputs and on social welfare oriented outputs. If the objective is more of a scientific one, the measurement will be based on academic outputs. The more the challenge is precisely defined (in terms of characteristics, properties, functionalities, etc) the more "objective" could be the measurement.

In the selected projects, goals are often expressed or could often be expressed in term of techno-social challenges or as a contributing to such challenges, even if it goes through solving some scientific issue. Then although it is the direction, no fully significant results have been observed yet: : it has not been really achieved yet, it is too early. But the scope of research has surely be open and broaden with the inclusion of socio-economic approach.

The overall goal is clear and accepted by all, at all level, with main issues being nitrogenation, overfishing and presence of toxic substances/pollution, the three aspects being interrelated. But

the question is how to formulate this in a more precise and contextualized way ? tons of pesticide ? % of cleaning ? etc probably, it has to be formulated in different ways that "speak" to the stakeholders, and be "declinated" in different projects as different sub-parts of the same overall goals. So issues of hierarchy of goals, and of "translation" of overarching goals into precise ones had to be taken on board in the critical mass approach. By the way, BONUS annual meeting is often precisely about that. For instance, alga problem is related to nitrogen problem, then sources has to be found in agriculture, fisheries, urban planing etc; thus in each of this area, a "version" of the goal has to be elaborated. Sometimes it is also the opportunity to use in a completely new and unexpetected way existing data coming from long series accumulated for years.

- "to secure a certain level of competences in a quite traditional area, i.e. for defensive reason" : not really at stake in BONUS, but it raises the problem of transmission of knowledge and the maintenance / evolution of research teams when key figures are leaving. This question is also important at project level : how to keep "alive" projects and "heritage of projects ".

- "to secure a certain level of competences in a very new area, i.e. for prospective reasons" : not essentially at stake in BONUS, but for instance the important issue of data / monitoring has been raised. Some data are accumulated withouth knowing all the possible use of them. It is important that researchers keep on being responsable of the data gathering and monitoring activities (not necessarily doing it, but at least via design and supervision). Example in Baltic sea : there are thousands of data on the transparency of water, and some series dates back to the 19e century. And nowadays they can be used for very specific analysis, correlating with different variables. But this activity need permanent (although not necessarity very high) funding and operations. Is it really corrsponding to this critical mass objective ? yes in the sense that it is about keeping option about something we do not know yet the possibility of. It is also about the "defensive" version of this objective in the sense that the knowledge used is not necessarily very revolutionary.

- “to reach self-sustained dynamics in the development of the area” is also important in BONUS. It is clear that a first step has been achieved. Taking into account the different possible ways of measurement :

• About the resources themselves, by looking at the quantity and quality of resources (including for instance the type of actors) that are mobilized in comparison with the "potential" resources that could be mobilized in a given field :

- directly or indirectly there are big and, for the time being, sufficient resources allocated to researchers at leat to launch the process (100 M € BONUS plus the leverage effects on national fundings, roughly ten times more according to some interviewees); but from another standpoint, BONUS may not be reaching the critical mass : 1.5 M€ (or 3 M€ with EC money) is small money as compared to the size of the problems regarding Baltic sea. But anyway, no country could not dedicate enough money on its own to address those problems, so there is a need to pool, at least to do something.
- all key research actors are in, at least at the bidding stage
- new types of actors (social science researchers) are also starting to be associated: this is an example of the creation of an embryon of a research community allowed through BONUS.
- access to research infrastructure (research vessels, instrumentations, computing facilities) is managed in a cooperative way, given that some countries have vessels but no money to make them work full time, other have few vessels but staff, other have many vessels with few time

available because they are working full time but have knowledge and expertise, countries do not have the same rules and regulation as regards the use of vessels and instruiments, etc. BONUS has set up special options to try to optimize these resources, and maybe in the future there wll be more convergence in that respect.

• At the level of participants, programmes and projects, by looking at the rate of answers to the calls, at the pervasiveness of the topics targeted by the programmes across the countries and regions, and by the convergence of the definition of those topics (in terms of classification used by programmes managers and owners):

- everybody nows about BONUS now at the institutinal and international level
- all Baltic countries are in
- all significant ministries, basic science agencies (sometimes 2 as in the case of some countries) and public bodies are in
- there is a general agreement on the topics of research and the way is paved for a enrichement of the perspective for including a larger scope of actors
- the scope of issues adressed, the mix of different disciplines involved and the different levels of approach (for instance calling - in the future - for agricuture side to be in when problem of nutrition are raised; or mixing climate change with study on fish flows etc) seems also more and more accepted as being the relevant one (researcher mobility and education are also to be taken into account in that perspective).

• at the level of the outputs, evaluation could be done in terms of rate of increase in the outputs produced, but as said it is too early (see above discussion on outputs)

• at the level of the relations between R&D actors, it is also clear that networking is increasing (see above) even if centrality and other measurements used for instance in social network analysis have not been implemented at this stage of the study.

In brief, it can be said that BONUS is clearly in the way to achieve this critical mass objective, having managed to bring together the basic conditions (or the determinants).

The interviewee also made two interesting remarks as regards the critical mass issue.

- Over a certain "size" (of programme, of projects etc), due to EC rules, the administrative burden becomes excessive and surpasses the benefit of pooling together; so critical mass should be considered also as an optimal mass, or along a range / an interval.
- One problem is to identify the few key real innovative and creative people, who have the resources and are in a favourable context to develop things (or could be in such a favorable situation with some support), and then will form the critical mass. Very often, there are only a few people required. In the US, the potential is so vast that those people can emerge. In the EU, the same potential exists but if one considers Europe as a whole. In this perpective there is probably too much "useless" competition between European countries (each one willing to have its own piece of cake) to favour the same process.

2.2.5 Factors relevant for achievement or non-achievement

The main factors in favour of the achievements of the critical mass objectives are at first place related to the external conditions that were extensively described earlier : a focus on common problems and quite homogeneous conditions (Baltic sea and marine/environmental research focus), pre-existing cooperation at different levels, alignement with policy and reglementary

inititiaves at global level; these really constitute a positive background and play as a pressure force towards the success.
Secondly, the dynamics seems to be really launched, associated to a quite pervasive participation of a large share of actors and the development of quite common view on issues and strategy. The momentum is clearly given, but an important threshold will have to be crossed in terms of agreement on strategy with the adoption of the Strategic Research Agenda.

Factors that could play against the achivement of the critical mass objectives seems to be more traditional and classical ones than specific ones. The lack of money could slow down the long term effort towards developing further networks, in a research environment with actors still scattered. As seen, there has been some criticisms towards the excess of bureaucracy and administrative burden, at all levels, during the first phase of projectss life. There should be streamlined interactions between agencies, BONUS and even EC in order to limit this in the future; the transition to Art 185 could solve part of the problems, but it it wll depend on the procedures and constraints imposed by this new institutionnal arrangements. And while ART185 was supposed to bring some homogenity and simplification, it appears that each of the 4 existing ART185 is different from the other, raising some concern for the future.

More broadly, one good thing is that BONUS is clearly in line with the overal EU strategy in marine/maritime field and for Baltic area. But the future success of BONUS also depends on the evolution of the long term policy objectives regarding environmental matters, the permanence of strategy and focus over time, and the coherence and coordination of different dimensions of this strategy suported by different Directorate of the EC. And at BONUS level, the achievement of critical mass objective type 1 will also be related to the capacity of the participants to translate the requirements and the general policy recommandations into a relevant design of research objectives.

2.3 Conclusions

It is very difficult to assess whether the level of public funding in the area related to BONUS is sufficient to allow researchers to provide answers to the technological, scientific and ultimately social and environmental issues raised in the case of Baltic sea. But it appears that the fundings through BONUS have at least be enough so far to launch a first momentum towards this goal. Now, the level of funding will have to be assessed case by case, ie for each topic or each specific issue deriving from the overall strategy that is in the process of being put in place.

As regards coverage, coordination and general organisation of the research in that field, it seems that BONUS heavily contribute to "glue" at research level the different initiatives taken at policy level (see the different EC strategy and initiative evoked above, between which a higher degree of coordination is probably required). Coordination between regional, national and BONUS seems to be adequate, although the way it is obtained and managed varies from one country to the other. It seems that there is no major gaps as far as the coverage of the area by the different European public R&D programmes is concerned, nor excessive overlap between the different European public R&D programmes.

In the framework of BONUS, competition between research teams seems to be at an adequate level, as it was attested by two different evaluations runned on the BONUS call process; moreover, the selection criteria tended to favour interdisciplinar projects, which is fully coherent with the BONUS strategy. The impact on the scientific excellence of the research projects supported can not be evaluated since the projects have not been completed yet; at least, a lot of top specialists in the field have been selected.

Apart from the funding aspect, the size and dimension of the overall BONUS fits the objective, as it was underlined notably in the analysis of the participants.

3 The ERA-NET ROAD

3.1 Introduction

ERA-NET ROAD seeks to start the process of coordinating national research programmes among its 11 member National Road Administrations (NRAs). It wants to see a mutual opening-up of national research programmes and to create an environment where transnational road research programmes can be devised and will flourish. To achieve these goals, project partners have set themselves a number of objectives which include:

• encouraging the exchange of information and best practice between NRAs;
• identifying and analyzing potentially complementary research themes;
• carrying out joint activities after identifying current research projects and programmes run by the NRAs that could be clustered together;
• developing strategies and programmes for transnational research activities, with common funding and calls for proposals;
• finding ways to ensure that the different structures, rules and administrative procedures within the NRAs do not hinder transnational co-operation;
• disseminating results to programme managers, research strategists and end-users across Europe.

Bringing the NRAs together in this way will certainly pack a financial punch – together they have a combined annual research budget of €156 million. In the spirit of helping to form a coherent European Research Area (ERA), the project partners have also made a commitment to help other NRAs to develop research strategies and programme that can contribute to European-level activities. ERA-NET ROAD's impact should last well beyond its three-year lifespan because it will lay down the procedures and practices that can be used time and again to devise and run transnational research programmes.

ERA-Net ROAD (ENR) has been initiated under FP6 and has meanwhile entered the second stage, with funding under FP7. As the coordinator has changed from FP6 (UK) to FP7 (FR) and a number of new participants entered in FP7, the activities under FP6 are being referred to as ENR1 while the FP7 version now is being called ENR2 (http://www.eranetroad.org).

The research field has already had a transnational / European structure before the ERA-Net experience: Conference of European Directors of Roads (CEDR; http://www.cedr.fr/, out of which the ERA-Net has grown as an initiative of only a part of the CEDR members.

The ERA-Net has been initiated by the UK Highways Agency in the course of the CEDR proceedings. CEDR had set up a "Technical Group Research", chaired by the UK, in order to address the issue of coordinating research. It turned out that not all CEDR members were equally interested in coordinating research. While the British were very keen on collaborating, Italy or Spain were less interested, so the interested countries agreed with the Governing Board of CEDR to put in a proposal for ERA-Net (however, later on, ES put money into the Road safety call, although not having become a member of the ERA-Net).

Research field: Road Research
Sector: Transport
Overlaps with other ERA-Nets: low, as ERA-Net Transport is more strategy driven and addresses different modes of transport, not only road transport (e.g. ROAD is focusing on road safety, while Transport on user safety). There had been meetings with ERA-Net Transport plenary group, other

platforms have been invited, too. The Commission wanted them to converge, but they do only split pots, while ROAD does common pots..
Duration: 3 years in FP6
EC funding: € 2 513 748 (FP6, Source: CORDIS)

11 Members from 11countries in the beginning:
Coordinator: United Kingdom: Highways Agency
List of Partners

23. United Kingdom: Highways Agency
24. The Netherlands: Directorate- General of Public Works and Water Management
25. Finland: Finnish Road Administration
26. Sweden: Swedish Road Administration
27. Germany: Federal Ministry of Transport, Building and Housing
28. Norway: Public Roads Administration
29. Switzerland: Office Federal des Routes
30. Austria: Federal Ministry of Transport, Innovation and Technology
31. Poland: General Directorate of National Roads and Motorways
32. Slovenia: Directorate of the Republic of Slovenia for Roads
33. Czech Republic: Road and Motorway Directorate of the Czech Republic

Entries / Exits: Denmark joined in 2007, CZ left, and Poland has become de-facto inactive (difficult to tell why, seems to have to do with internal re-organisation)
In ENR2 four more national road administrations joined (FR, IE, HU, LT), one regional partner (Flanders) and several programme managers. There was also a workpackage on broadening, with the result that there are now talks with Cyprus, Malta and Latvia.

This report is based on the following sources:

- Basic information from CORDIS
- Responses of coordinator and one participant to CRIMASS online survey (*status of 26 January 2011*).
- In-depth interviews with the coordinator and three partners
- Beneficiaries answers (*not applicable for this ERA-NET*)

3.2 Critical Mass analysis

3.2.1 External factors and policy objectives related to Critical Mass

We understand "critical mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field.

According to what the interviewees indicated, the ERA-Net's objectives are:

- To address socio-technological challenge, here: mostly questions of climate change, but also road mobility (traffic jams, intelligent road management…) (coordinator)
- To secure a certain level of competences in a quite traditional area, i the transnational engagement gave access to information, that helped to get/maintain the most important topics on the national research agendas i.e. they understand this to happen not at the level

of researchers (as we defined it, but at the level of programme owners), (coordinator and one participant)

- To reach excellence, reduce duplication, improve quality (coordinator, but one partner says that this is not the primary aim)
- To reach self-sustained dynamics in the development of the area, (very much understood in the same way than "securing a level of competence"; by coordinator)

To conclude, addressing socio-technological challenges and reaching excellence do apply in the sense we have defined it, i.e. at the level of researchers. The objectives of securing a level of competence and reaching self-sustained dynamics are not really understood by the interviewees as taking place at the level of the researchers but at the level national road administrations and programme owners.

Secondly, the policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees. The interviewees characterize road research as a mature research field. For the UK one could also say that it is in decline (e.g. 10, 11 years ago the national road research laboratory has been privatized, now TRL). The research is dominated by a few key actors (e.g. in UK: TRL, Halcrow, PB, WSP, Jacobs, Mott maccdonald, Scott Wilson, Arup, Atkins). Leading countries in Europe are DE, NL, UK and FR. The research in Europe can be regarded as world-wide leading, with US research being ranked second after the EU. However, there is currently duplicate research in Europe. Road research requires partly large physical infrastructures, e.g. road pavements testing areas, for instance, for testing road resistance (deflectographs). DK, US, UK have one each, i.e. this infrastructure is available in the EU. Moreover, it is heavily connected to ongoing research activities in other fields as user of the results from this research. Main clients are public authorities who require new type pavements (less energy intensive in production, less noise, more durable in changing climate conditions, more innovative traffic management systems, more safety). There is no real private market.

Most obviously from these descriptions appear the following types of objectives:

- To address socio-technological challenge, addressing issues of energy, climate change, mobility, safety.
- "To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons", understood as keeping the advantageous position vis-à-vis the US, also by reducing duplicate research. (This last point would also support the view to see this as an issue of reaching excellence by pooling resources in order to compete with the US and others. However, one participant mentioned that this was not the primary goal, so the motivation to compete with the US is perhaps better described by securing a level of competence.)

3.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give some indication on what kind of achievements can be expected. The approach to set up a strategic action plan for planning the joint activities and the efforts to build a sustainable network structure in order to set up a durable cooperation at European level point to the CM objective of addressing a socio-technological challenge. The joint calls, although small in the beginning, clearly reveal the goal of bringing together researchers in Europe at an increasing level and should be able to show some impact with respect to securing a level of competence.

- **Joint activities**: Three pilot project calls, followed by two thematic calls (safety and climate change), followed in FP 7 by larger calls. All larger calls refer to the priority list of the network, which is not a real transnational programme, but a strategy. All calls are common pots.
- The **non R&D activities** are particularly interesting: **priority assignment** was done early on in order to start with programme calls (fits into category "Action plan taking up common strategic issues and preparing for joint activities"). In the early stages the research topics were determined by the "method" of the lowest common denominator. This entailed long discussions about the course of action and yielded no real impacts. Today ENR provides more a focused way: They organize workshops, elaborate research needs (which do not have to be commonly agreed upon) and sent the topic to all network members. The decision to take part in a joint call is left open to each RD ("who is in, is in").
- More non R&D activities include, the **database on national projects is a peculiarity,** the RRAF (Road Reseach Access Facility): fits into the first category of non R&D activities ("Coordination / Clustering of ongoing nationally funded research projects", although France and NL do not share their information in this database). The **administration toolkit** to overcome many national differences in funding priorities and funding schemes is very special, too. Finally, the preparations for **sustainability of the cooperation** after ERA-Net funding stops have started early on and are currently being negotiated in the CEDR context, however, have not yet been successful either.

3.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives an assessment on the achievements of the exercise.

Critical Mass of Funding budgets:

- Coverage of relevant countries: NO according to coordinator: Italy, Spain and Portugal are missing. Comment: They don't appreciate the benefit of trans-national programming. In PT, the universities wanted to join, but there was no support from national road directorate. One participant says that also Greece is missing.
- In ENR2 four more national road administrations joined (FR, IE, HU, LT), one regional partner (Flanders) and several programme managers. There was also a workpackage on broadening, but the result seems so far, that it is going to be Cyprus, Malta and Latvia.
- One of the ENR II objectives is also to pave the way towards achieving an expenditure of 10% of the research budget of the National Road Administrations on trans-nationally funded collaborative research by 2013.
- Three pilot project calls, with for each 6 or 7 out of 11 members participating; two thematic calls (Climate change and safety), will ALL members participating in each.
- COMMON POT Funding, however, size of pots small for pilot project calls (only one project funded each: 110, 126 and 204 k EURO), and somewhat larger for the two programme calls (1.35 and 1.485 mill Euro). In ENR2, they aimed at creating larger pots (goal was to raise 3 mill in the first call, while 2.85 has been raised, now for second call goal is to raise 6 mill, 5 mill have been raised).
- Contributions of partners: In most cases there were meaningful financial commitments given as compared to their national budgets.

- There is added value of investments. If one partner devotes only 100k Euros the project will be rather limited. If 10 partners join forces you have a pot of 1 Mio and larger and probably more effective projects.

➔ Author's comment: Although relevant countries are still missing, there is a constant effort towards broadening visible, as well as towards increasing the pots.

Critical Mass of Researchers:

- Mostly, excellent researchers have been participating in calls.
- However, not all relevant researchers can be attracted yet by the ERA-Net calls. Many researchers say, that they do not have the international contacts. Some participating road administrations try to help with partnering, so far on an occasional basis.
- In the view of CEDR the quality of ROAD projects is better than in other contexts (national projects, FP projects etc.).
- One participant expects RADICALLY new results.
- European countries together can be regarded as world-leading in the field (UK, DE, NL and FR), each country alone is competitive vis-à-vis the US, they need transnational European collaboration.

➔ Author's comment: There is a clear to do in order to reach crimass in future: organize partnering events, databases and similar in order to make the relevant research suppliers participate. Apart from this, also positive indications.

3.2.4 Critical Mass objective achievement

In this section, we report how respondents assess the achievement of objectives and, secondly, how the level of achievement can be judged based on output indicators.

The first aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

According to one participant's general assessment there is clearly a new impact by the ERA-Net. The objectives could not have been reached in such an elaborated manner without the ERA-Net initiative.

Answer from coordinator and participant: With respect to objectives mentioned above, steps have been made forward.

- To address socio-technological challenge (coordinator)
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (1 partner)
- To reach excellence (coordinator)
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (coordinator)

Except for the fact, that the respondents might think of the last one as happening at the level of the programme coordinators rather than at researcher level, this goes in line with what has been found for the activities (and is similar to the CM objectives identified in section 2.1).

Secondly, we look at the list of output indicators as reported by the interviewees and survey respondents. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can now do a check which CM type is best supported by the

output profiles given by the interviewees. According to one interviewee, one serious deficit of ROAD is that – being a research driven network – its research results are far from being implemented or, even, implementable. On other words, research is still far away from practical application and knowledge and technology transfer hardy functions. This lack of outcomes is also mirrored in the overview below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-techn. Challenge	New processes, products and services;	Not all most important indicators are witnessed Other, less important indicators not witnessed, too.	*Agreement by respondents, but overall small evidence.*
Address scientific challenge	*n.a.*		
Securing a level of competence (defensive)	New or improved processes etc.,	Not all most important indicators are witnessed Other, less important indicators mostly not witnessed, too.	*Agreement by respondents, but overall small evidence.*
Securing a level of competence (prospective)	*Similar to defensive CM, but logically, it can only be one of them.*		
Reach Excellence			*Nothing reported by respondents to survey, but some qualitative remarks from interviewees.*
Self-sustained dynamics	networking, increasing number of actors active in the field	Not all most important indicators are witnessed Other, less important indicators not witnessed, too.	*Agreement by respondents, but overall small evidence.* *In author's view less applicable as an objective for this ERA-Net.*

Overall, addressing a socio-technological challenge, securing a level of competence, and reaching self-sustained dynamics are somewhat supported according to indicators compared to other types. For reaching excellence, the interviewees gave some qualitative indications (which can be found in section 2.3 under the headline "Critical Mass of Researchers").

According, to the author's assessment, most important among these objectives seems to be to address a socio-technological challenge, as it has been identified from the beginning at least by the coordinator, and it fits to the peculiarities of the field. Also, securing a level of competence was for this reason identified. Reaching self-sustained dynamics is in the author's view (see above section 2.1) not very well applicable here.

So, overall, one can concede only small progress with respect to addressing socio-technological challenge, and to securing a level of competence as compared to the US. For the two, one might however reasonably assume, that more supportive outcomes will be witnessed in the future.

3.2.5 Factors relevant for achievement or non-achievement

While we describe in section 2.1 possibly relevant environmental conditions and in section 2.2 possibly relevant determinants (activities), we arrive in sections 2.3 and 2.4 at the results and level of achievement. In this section we draw a first analytical conclusion from this case study about

which of the above mentioned factors (either environmental conditions or something related to ERA-NET activities) appears to be a relevant factor for (non-)achievement of CM. The statements are based on the indicators or other evidence from the interviews in this case study.

- **Individual rationales / national interests going beyond learning or networking:**
  - There is a will to create transnational projects and open up individual programmes, and one partner even has the aim not to do any project nationally, until they have explored to do it internationally.
  - One partner has its own national strategic agenda oriented towards "socio-technological challenges", such as "green" transport and safety.
  - All countries have more or less the same problems: traffic fatality, CO2 emission, noise etc.. These common interests make it easier to collaborate than in other areas.
- **Engaged coordinator for the pooling of resources**:
  - Coordinator wants "Creating and supporting transnational projects in a field which requires transnational cooperation", i.e. a pooling of resources.
  - Coordinator has aimed to influence ERA-net goals in order to make them fit with their own national agenda. So the participation has brought about for them a better definition of goals, but also a new / different viewpoint on goals. They think they can reach climate change policy better at a European level than at national level.
  - They have set up early preparatory activities for post-funding phase in order to create a sustainable structure for R&D collaboration.
  - Most participants regard the joint transnational activities as effective, but stress that there is still some more implementation/dissemination needed.
- **In case of too diverse expectations and national interests, the coordinator needs to build up trust among the participants and to mediate participants' interests into a common agenda.**
  - The motivation in the beginning was very much about "trust, understanding and commitment", there were only two small pilot projects in the first year.
  - An administration toolkit was developed to overcome many national differences in funding priorities and funding schemes.
- **In case of successful interest mediation, it requires that the national representatives can convince their authorities at home of the potential merits of the collaboration and hence of the need to commit (more) funding.**
  - National administrations (in particular those actors not directly involved in international collaboration but responsible for money allocation) have to be convinced of the merit of pooling funding at international level, i.e. that it is not money for hobby horses, but well invested money, as it brings about higher value for money.
  - For some Road Directorates (RD) the topics treated are new. Most of the RD probably would not have engaged in these topics.
  - By connecting themselves internationally and defining research priorities, the representatives could convince their colleagues in the national administrations of the need to do this effort. In UK, this has been done mostly on the basis of testimonies of actors benefitting from the ERA-net actions. In particular, the value

of the RRAF database is estimated as being very high, the overall increase in knowledge about what other road administrations do and what kind of research is being done. This has helped to convince the NRA to continue with its engagement in the ERA-net and to commit more and more budget.

3.3 Conclusions

The organisation of road research in ERA-Net ROAD has indeed brought about added value. While there has been international collaboration at the level of CEDR before, ROAD raises this to a new level with the clear aim of pooling funding and of joining R&D activities in order to reduce duplicate research, which is currently the case. Joining forces in Europe seems necessary, as European countries only jointly can be competitive vis-à-vis the US.

It is not yet the case that all relevant countries are taking part in the ERA-Net, and the amount of funding pooled in the calls has been very small in the beginning and could only very recently being raised remarkably. Also, still not all relevant researchers can be reached by the calls.

Given the set of activities and the engagement of the coordinator in the first phase of ENR and given the promising new calls as well as enlargement by new participants of the second funding phase, one can reasonably assume that this ERA-Net will be able to reach more researchers in Europe and really contribute ERA-development in this field. One will have to expect how effective and successful the new coordinator of ENR II will continue the work.

4 The ERA-NET ERA SysBio

4.1 Introduction

ERASySBIO is a transnational funding initiative to support the convergence of life sciences ("classical" experimental ("wet lab") biology) with information technology & systems science ("dry lab" simulation, modeling…). The ERASysBio Coordination Action springs from a Specific Support Action (SSA) that has already laid the foundations of this new network. It brings together funding agencies from 13 countries including Israel and Russia. Associate partners Luxembourg and Switzerland are expected to join later. It will build not only on national programmes in systems biology but also upon several European efforts springing from EUREKA, the European Science Foundation, the European Molecular Biology Laboratory and several other EU-supported projects. It will also help in the development of drugs specific to small groups of people or even individuals, made possible by new insights from genome research. Outside medicine, systems biology is likely to have a big impact on agriculture and biotechnology and is expected to be a major contributor to Europe's industrial future.

Research Fields: Biotechnology, Food, agriculture and fisheries, Health
Sector: Life Sciences
Overlaps with other ERA-NETS: some in the pathogens sector with Pathogenomics ERA-NET and in Micro Organisms of industrial interest with ERA-IB
Duration: 5 yrs from 2006, FP7 proposal under way, ERA-Net+ call with FP7 funding in 2010
EC funding: 2,950,000 € (CORDIS)

12 members of 11 countries in the beginning:
Coordinator: Project Management Juelich (PTJ), Germany
List of partners:

1. Austria: Austrian Ministry of Science and Research (BMWF)
2. Finland: Academy of Finland (AKA)
3. France: National Research Agency (ANR)
4. Germany: Federal Ministry of Education and Research (BMBF)
5. Israel: Israel Science Foundation (ISF)
6. Netherlands: Netherlands Organisation for Health Research and Development (ZonMw)
7. Slovenia: Ministry of Higher Education, Science and Technology (MHEST)
8. Spain: Ministry of Science and Innovation (MICINN)
9. United Kingdom: Biotechnology and Biological Sciences Research Council (BBSRC)
10. Regional partner: Trento / Italy
11. Russia (RSBR)

Affiliated:

1. Luxembourg: National Fund for Research (FNR)
2. Switzerland (SNF)

Entries/Exits: Belgium (FNRS) and Norway (RCN) as additional participants

- Additional French partner: CNRS
- Additional Dutch partner: NWO

This report is based on the following sources:

- Basic information from CORDIS
- Responses of coordinator and two participants to CRIMASS online survey *(status of 19-01-11)*
- In-depth interviews with the coordinator and three partners
- Beneficiaries answers (*not yet included*)

4.2 Critical Mass analysis

4.2.1 External factors and policy objectives related to Critical Mass

We understand "critical mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field.

According to the Coordinator and two participants the answers shows high agreement for the objective “Securing a level of competence for prospective reasons”, followed by the view of two respondents that reaching excellence and self-sustained dynamics applies, too:

- “to address a Socio-technological challenge” (1 partner)
- “To secure a certain level of competences in a very new area, i.e. for prospective reasons”: There are only few people in some countries, who have to be brought together (by all 3)
- “to reach excellence”: self-evident, area of basic research (2: coordinator and one partner)
- “to reach self-sustained dynamics in the development of the area”: meaning that bringing together different disciplines in order to jointly undertake this research; meaning also that young researchers have to be trained (biologists have to be trained in possibilities of using information technologies, and information scientists have to be trained to understand experimental biology) – very similar understood to reaching a level of competence above (2: coordinator and one partner).

Secondly, the policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

Systems biology is a quite young research area. ERASysBio aims to bring together the wet lab and dry lab communities at European level, but even more, it aims at establishing data management standards. Data Management is a central question of this field. As it is only emerging, researchers have to commit themselves to issues of data quality and data management. Data management means that there must be standards on how to pool and share existing knowledge of the field, i.e. knowledge about which experiments have been done with which organisms, what kind of data have been used and generated using computer modeling and simulation techniques, what kind of SOPs (standard operation procedures) have been used and generated, what kind of programme codes and routines have been written etc. The field of information sciences does not use the way of publication intensively, but rather conference proceedings or programming language platforms to disseminate and share their knowledge.

Systems Biology is “partly dependent on large physical infrastructure only available in one or a very few places”, which are available in the EU. They require centers with combined facilities for experiments (labs) and data processing (computers, servers); see also below.

Most obviously from these descriptions appear the following types of objectives (which have also been mentioned by the interviewees):

- "To secure a certain level of competences in a very new area, i.e. for prospective reasons"
- "to reach self-sustained dynamics in the development of the area"

4.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give first indication on what kind of achievements can be expected. Although systems biology is likely to have an impact on health research and other applications, including a most probable relevance also for socio-technological and scientific challenges, the activities of the ERA-Net, in particular non-R&D related activities, are likely to contribute mostly the above mentioned objectives ("prospective CM" and "self-sustained dynamics"). As for the R&D activities, i.e. the calls, also the excellence objective or addressing a socio-technological or scientific challenge would apply.

- Joint activities: **Calls:** SYSMO and SYSMO II (Systems biology of microorganisms – can be considered as a joint programme) – see www.sysmo.net (large virtual pots, 28 mill.€ and 17.7 mill. €, with very large shares coming from Germany, about 40%), 1 ERA-net + call (FP7 funding, mixed mode (EU money as common pot), 24 mill. €, see www.erasysbio.net). The SYSMO calls had 6 and 5 partners on board, but SYSMO I was already set up before the ERA-Net started. For ERA-Net + call, there were 10 partners. Each call has also included a central data management project.
- **Infrastructure**: Systems is "Partly dependent on large physical Infrastructure only available in one or a very few places", which are available in the EU. They require centers with combined facilities for experiments (labs) and data processing (computers, servers). Approx. 35 centers are in the ERA-Net partner countries. Further centers are needed and more networking among them (virtual infrastructure); real cluster building is not needed. Without having this planned, it more and more appeared to be a good idea, to submit an **ESFRI proposal** (Road map for infrastructures). The idea is to set up a virtual infrastructure among centers. Most likely, this will be included in the ESFRI roadmap.
- Many other non R&D activities with high importance. Most important is **data management**: All projects funded have to have a workpackage on data management and share data on their research within a centrally managed database (in particular information about program codes, type of data which they are using or generating, type of organism they are studying). The researchers have to inform about their data, but still have control over their raw data, they can decide whom to give access to raw data. Currently, they are about to publish a **"Data sharing policy".** Interesting – and a very important activity according to the MICINN/ Spain – are **joint summer schools**, and the advancement with new PhD curriculae (Workshop and individual initiatives of researchers who are also active in the ERASysBio calls).

4.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives an assessment on the achievements of the exercise.

Critical Mass of Funding budgets:

- Coverage of relevant countries: ERASysBio has now 16 partners from 13 countries. They have almost all of the relevant (in terms of scientific excellence) countries on board, with the exception of Switzerland, and maybe Italy. The Swiss obviously focus in their international networking more on countries outside EU (i.e. the US).

- 5 and 6 partners in calls (but for SYSMO 1 at that time- before the ERA-Net started- the then "whole" group of countries (of the SSA), 10 partners in ERA-Net plus call
- Very large pots (28 mill.€ and 17.7 mill. €, and 24 mill. For ERA-Net+ call)
- Most partners have made substantial funding contributions, only two earmarked too few budget in a call, but they extended their budgets later on.
- Virtual pots (and +call as mixed mode), common pot is being regarded not as efficient.
- National programmes are often more general, no specialised systems biology programs.
- In Spain, ERA-Net responsibilities will be transferred from the international department to the technical department. This will be a benefit, because International cooperation will not lose touch with National Programmes and because of the budget, International budget is too low.

➔ Author's comment: Having no specialized thematic programme at national level which fits into the ERA-Net scope is not a caveheat for remarkable national commitments. For some countries, the ERA-Net activities might even help to increase national awareness for the topic and lead to higher national funding. However, not all countries are participating in the calls, although 10 countries in the most recent ERA-Net +-call is a very good result.

Critical Mass of Researchers:

- World-leading in research field: In Europe, UK, NL, DE and CH are leading, outside, there are the US and Japan. The coordinator could not give a clear indication, which would be the leading country among the others.
- Swiss (and perhaps Italian) communities missing.
- Large group of beneficiaries.
- In the first call, they had not restricted number of partners, so consortia were quite large and difficult to handle. The second and third call set a maximum to five partners. Most projects are at this maximum. Minimum is three partners (from three countries).
- This and other ERA-NET joint calls attract actors who have not applied for national funding before. The calls did and do mobilize new applicants or research groups in some partner countries.
- There are non-partner countries with groups participating in the transnational research projects of the ERA-Net+ call are: IT, IS, US and ZA.
- At the ERA-Net level they do not do a monitoring of excellent output (would require counting conference proceedings, publication of programme routines etc.)
- According to their knowledge, excellent researchers have taken part in the calls.
- They are expecting radically new results from the projects.
- One partner sees a new type of research projects being funded at national level, and more ambitious research projects being funded at national level. Moreover, a significant evidence of access to foreign communities has been experienced

➔ Author's comment: Mostly, positive indications. Except for the Swiss scientific community, many relevant researchers are part of the exercise.

Critical Mass of Infrastructure:

- Have done proposal for ESFRI roadmap to set up a virtual network of centers.

➔ Author's comment: Impact not (yet) visible, but would not have happened without ERA-Net.

Critical Mass of intangible resources, here data management and quality standards:

- Have done several data management projects.
- All projects are required to contribute to this effort.
- Working on a data sharing policy.

➔ Author's comment: Impact not (yet) visible, but would not have happened without ERA-Net.

4.2.4 Critical Mass objective achievement

In this section, we report how respondents assess the achievement of objectives and, secondly, how the level of achievement can be judged based on output indicators.

The first aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

There are only answers from two respondents (coordinator and one partner). They are different from above and there is no clear agreement visible among the respondents.

- "to address a Socio-technological challenge" (partner)
- "To address a scientific challenge": some diseases are addressed. Systems biology allows reaching at new results where classical experimental biology has come to an end (coordinator)
- "To secure a certain level of competences in a very new area, i.e. for prospective reasons": CM is not yet reached, area is still new (partner)
- "to reach excellence" (coordinator)
- "to reach self-sustained dynamics in the development of the area": not yet reached, would EC funding stop now, the efforts to establish common data quality standards in the field for example would stop without having been realized in a sustainable manner (coordinator)

Secondly, we look at the list of output indicators as reported by the interviewees. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can now do a check which CM type is best supported by the output profiles given by the interviewees. There are some discrepancies by the respondents, as can be seen in the table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New processes, products and services; standards, norms.	Only indicated by one respondent, except for one (standards, norms). Other important and less important indicators mostly missing.	*No real agreement by respondents; in author's view only a vey indirect objective.*
Address scientific challenge	Scientific publications, creation of access to new research fields	The most important indicators are witnessed / expected by both.	*Has not been identified explicitly as an objective in section 2.1.*
Securing a level of competence (defensive)	*n.a. according to section 2.1*		
Securing a level of competence	Scientific publications.	Witnessed / expected by both, but new research contracts missing. Other less	

(prospective)		important indicators are only witnessed by coordinator.	
Reach Excellence	Scientific publications, patents, improved position in international ranking.	Most important indicators are witnessed / expected, but two of them only by one respondent.	*Has not been identified explicitly as an objective in section 2.1.*
Self-sustained dynamics	Patents, Scientific publications, additional researchers, networking, increasing number of actors active in the field	The most important indicators are witnessed / expected, three of them by both. Two indicators of minor importance are witnessed, too.	

Overall, addressing a scientific challenge and reaching self-sustained dynamics are very clearly supported according to indicators. There is also evidence for reaching excellence, but there is more disagreement here.

According, to the author's assessment, most important among these objectives seems to be self sustained dynamics, as it has been identified from the beginning by all participants as one of the major objectives. This is also clear form the fact, that they themselves value the respective indicators for this CM type very high (training activities such as summer schools and PhD curriculae), increasing number of active researchers in the field etc. Moreover, it has also been identified by the author based on the peculiarities of the field.

As has been shown, there is progress with respect to reaching self-sustained dynamics, although they agree that the field has not yet reached a level of sustainability, where it could develop further without EC funding. Securing a level of competence for prospective reasons is not so clearly supported by the indicators, however, in the context here, it is not completely separable from self-sustained dynamics, so one should not conclude that the ERA-Net misses to reach an important objective related to CM.

4.2.5 Factors relevant for achievement or non-achievement

While we describe in section 2.1 possibly relevant environmental conditions and in section 2.2 possibly relevant determinants (activities), we arrive in sections 2.3 and 2.4 at the results and level of achievement. In this section we draw a first analytical conclusion from this case study about which of the above mentioned factors (either environmental conditions or something related to ERA-NET activities) appears to be a relevant factor for (non-)achievement of CM. The statements are based on the indicators or other evidence from the interviews in this case study.

- **Basic scientific / technological knowledge base:** Partners only decide to commit funding for a call, if the scientific community is in a good position to take part in it.
- **Individual rationales / national interests going beyond learning or networking:**
  - For coordinator: Improving own / national R& D programmes: in the sense of more internationalisation of programmes (spending more budget internationally).
  - Entering into collaborative research on EU level in the System Biology field, where partners have no own thematic programme.
  - Pursue a policy that facilitates national and international collaboration between researchers at an excellent level.
- **Very good and engaged coordinator**:
  - It seems that they have a very good overview on all activities happening at EU level, they know the instruments and have linked up with important initiatives (ESFRI

roadmap, working group on knowledge based bio-economy on synthetical biology, FutureSysBio, ESF etc.) and have thus united all the single approaches and gave quite a coherent framework to them.

  - The ERASysBio is best coordinated among all ERA-NETs (according to one respondent from a smaller country).

- **Well-focussed and continuous (R&D) activities:** In the opinion of one interviewee, if the scope of a joint call is well focused, and there is also continuity, it is possible to expect to reach critical mass. This not yet applies for ERASysBio, being an emerging network at national and transnational level. SYSMO is a start into this direction, it can be considered as a joint programme.
- **National representatives need to be political, i.e. they should see and convince their authorities at home of the potential merits of the collaboration and hence of the need to commit (more) funding.**
  - In Spain, ERA-Net responsibilities will be transferred from the international department to the technical department. This will be a benefit, because International cooperation will not lose touch with National Programmes and because of the budget, International budget is too low.
- **Critical Mass is <u>not</u> necessarily linked to increasing scale of projects**: In the first call, they had not restricted number of partners, so consortia were too large and difficult to handle. The second and third call set a maximum to five partners. Most projects are at this maximum. Minimum is three partners (from three countries).
- **Opening up to the world can be a supportive factor:** ERA-Net+ call funded also beneficiaries from non-partner countries (in effect some from IT, US, IS and ZA). A systematic opening towards the world, in particular the US, could be a means to win those European countries for collaboration, whose communities are already very much oriented towards the US (here, this applies to the Swiss community).
- **Reaching CM at the individual (national) level is easier for smaller countries**:
  - For a small country the ERA-Net very clearly helps to individually achieve CM.
  - Smaller countries might feel dominated by larger countries, however, these commit much more resources and capacity, and they have more need to influence the policy of the ERA-Net in order to have benefit. On the other hand the smaller participants would not appreciate to be in an ERA-Net in which no large country is involved.

4.3 Conclusions

As an emerging area of research, Systems Biology, is also only about to attract interest as a topic of public funding activities. In many countries, there are no specialised programmes yet. Often, the topic is funded by general health research programmes, but the research field does not only contribute to medical questions but also to others such as agriculture. Therefore, establishing ERA SysBio has clearly contributed to raising awareness for the field as a subject of research and innovation policy. Pooling funding at European level clearly generates added value to national activities, which are often only occasionally, restricted in scope or even non-existent.

ERA SysBio has succeeded in pooling very large (virtual) pots, with the relevant countries on board, except for Switzerland, who are more oriented towards the US. The ERA-Net + call was welcomed

and used as a means to open up to research communities not present in the ERA-NET (i.e. IT, IS, US, ZA). A systematic opening towards the world, in particular the US, could be a means to win those European countries for sustainable collaboration, whose communities are already very much oriented towards the US (here, this applies to the Swiss community).

Overall, the field is judged to be dependent on international collaboration, as it is only emerging, as the national communities are still small, and therefore not able to reach a critical mass of their own. The group of beneficiaries reached by the ERA-Net calls is large, despite the fact that the size of projects is restricted to five partner groups in order to avoid coordination losses. This seems to work very well, as the outputs of the projects are quite promising.

Systems biology research moreover requires the pooling of other resources, such as infrastructure, in particular research centers, which combine computation capacities with laboratory equipment, as well as a more intangible type of resources, i.e. data management and quality standards. Both types of resources profit from being pooled at an international level, where large parts of the community are reached. ERA SysBio has contributed enormously to both topics, in particular to the data management issue and has done a lot of networking in the field in order to integrate as many of the activities as possible.

5 The ERA-NET EuroTrans-Bio

5.1 Introduction

European Biotechnology SME's are facing a challenge to gain a critical size on the market in terms of RTD project portfolio, scientific and managerial excellence. Currently, national RTD programmes for biotechnology SME's and public research laboratories do exist in many EU member states. However, trans-national funding within the national/regional programmes is not common. In the European Community, trans-national public-private partnerships could achieve synergy effects, reduce risks and costs in R&D projects and thus gain benefits in competitiveness. The aim of the EUROTRANS-BIO (ETB) project is to commit ministries and government agencies from Member States (Austria, Finland, France, Germany, the Netherlands, Spain/Basque) in the design and the implementation of a truly integrated trans-national RTD programme. Such an activity will develop best practices, establish cross-border partnerships between SME's and/or public research laboratories, strengthen European efforts to achieve sustainable development and disseminate best practices.
ETB is continued by ETB-PRO which will reduce the fragmentation of ERA and support high quality R&D project cooperation of European biotech SMEs by building on success factors of the ETB and establish a sustainable joint program with high funding impact. This will be done in two steps thereby using four calls with a funding volume of 35 Mio each as an implementation tool.

Research Fields: Biotechnology
Sector: Life Sciences
Overlaps with other ERA-NETS:
Duration: 51 months, start: 01-10-2004, end: 31-12-2008, Project cost: 2893950 € and project funding : 2893950€ (Cordis)
ETB-PRO (PF7): 48 months, start: 01-01-2009, end: 31-12-2012, Project cost: 3728607€ and project funding: 3166533€

12 members of 6 countries in the beginning:
Coordinator: OSEO innovation regional offices, France
List of partners:

1. Spain: Basque government-industry, trade and tourism deparment
2. Netherlands: senternovem, Department of the Dutch Ministry of Economic Affairs, Agriculture and Innovation
3. Austria: Bundesministerium für Wirtschaft, Famile un Jungend– Ministry of Economics, Family and Youth
4. Germany: Bundesministerium für Bildung und Forschung - German Federal Ministry of Education and Research
5. Germany: Forschungszentrum Juelich gmbh
6. Austria: Österreichische Forschungsförderungsgesellschaft mbh, Funding agency
7. Finland: Finnish funding agency for technology and innovation
8. France: Ministry of economy, finance and industry - general directorate for enterprise –
9. France: Ministry for higher education and research
10. Netherlands: ministry of economic affairs
11. Spain: Sociedad para la promocion y reconversion industrial

Entries/Exits: New Coordinator: BMWFJ, Austria

All the French partners exit ETB

Entries:

1. Belgium: Instituut voor de aanmoediging van innovatie door wetenschap en technologie in vlaanderen belge – IWF (flanders)
2. Spain: Agencia vasca de la innovacion-berrikuntzaren euskal agentzia - innobasque - (basque country)
3. Italy: Ministero dello sviluppo economico – Ministry of Economic Development
4. Hungary: Memzeti kutatasi es technologiai hivatal hongrois – NIH
5. Belgium: Service public de wallonie (Wallonia)
6. Italy: Istituto per la promozione industriale – IPI
7. Spain: acc1ó - (Catalonia)
8. Spain: DIEE-GN - (Navarra)
9. Spain: IMADE – (Madrid)
10. Israel: MATIMOP

This report is based on the following sources:

- Basic information from CORDIS
- Responses of four participants to CRIMASS online survey *(status of 31-01-11)*
- In-depth interviews with the coordinator and three partners
- No Beneficiaries answers

5.2 Critical Mass analysis

5.2.1 External factors and policy objectives related to Critical Mass

We understand "critical mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field.

According to four participants, the answer show high agreement for the objective “to reach a self-sustained dynamics in the development of the area” followed by “to secure a certain level of competences in very new areas”:

- “to address socio-technological challenge" (1 partner)
- “to secure a certain level of competences in a very new area” (2 partners)
- “to reach excellence” (1 partner)
- “to reach self-sustained dynamics in the development of the area” (3 partners) The idea is to increase the networking of SMEs in order for them to become more visible internationally. The aim is to create an environment in which trans-national cooperation for biotech SMEs is possible. ETB could become an attractor to involve more countries.

Secondly the policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/interviewees.

The biotech industry is characterised by small sized and young companies (very often less than 10 years old) with an important and increasing need for international cooperation. The objective of ETB was to prevent the lack for international cooperation. There were not many possibilities for getting funds for international cooperation in national programmes. Moreover SMEs had few

chances to get funds under classical FP6 programmes because the funded consortium were of relative large size, or at least of a size which is not adequate for SMEs' needs. Moreover for some development projects in the biotech sector there is no need to build up a large consortium. In other word the tools of the FP6 programmes were mostly not adapted for small and young biotech companies.
For many participants, the main motivation to enter ETB was to bring their biotech industry to the international scenery and to incentivise the firms to enter international cooperation. What existed in international cooperation in 2004-5 was far from the potential of what could be achieved. The Era-Net offered the possibility to gain high impact with relative low efforts.
ETB covered a niche: to fund applied research and development projects – in small international consortia – for young and small biotech companies in some European countries. The funded projects are rather market-oriented: the objective is to develop a product/process.
During the first Era-Net all the countries shared the same vision about the need to fulfil this niche.

Most obviously from these descriptions appear the following objective (which have also been mentioned by the interviewees):

- "to reach self-sustained dynamics in the development of the area

5.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give first indication on what kind of achievements can be expected.
ETB was mainly dedicated to calls. But in order to prepare this, they followed the classical four steps:

- Mapping : as the main target is SME, it required to identify existing programmes that fitted with the ETB desired one, ie with SMEs as main target, application orientation, collaboration allowed with small consortia, and benefits clearly oriented towards industry
- Building a vision paper which was the basis of the FP7 proposal – the idea was to build a sustainable joint program with 4 calls during ETB and optimising the process to have enough money for the 4 calls
- Doing something together
- Launching joint calls

In FP7 the main view was to develop a sustainable programme with yearly calls, with countries being able to keep working without EC support.

- Calls: From 2006 to 2009 ETB has launched 4 calls for transnational R&D projects. The network of projects spans across Europe with the majority of projects being bilateral cooperation. A typical ETB project involves two or three SMEs and one partner from a research organization. In four calls EUROTRANS-BIO generated 170 proposals for innovative industrial research and development projects. By the end of these four calls, an estimated total of € 79 million of funding has been awarded to 81 recommended projects. This in turn has mobilised a further € 61 million of industry finance to cover the overall project costs of € 140 million. Some 203 SMEs together with 66 academic partners and six large industrial groups are benefiting from ETB funding. The majority of projects are found in the health sector (medical diagnostics; red biotech: 82%) followed by Agro-Food (green biotech: 11%). Industrial biotech (white/grey biotech) and marine biotech (blue biotech)

applications account for 7%. The 6th transnational call is currently open and will end 1st of February 2011.

- Learning effect: Calls were experimentation tools: they learnt how to decrease the cost of running a call by creating synergies in some areas and squeezing money in some others. They did continuous improvements between the different calls with some incremental changes. For instance they started with a 2 steps application in which it took 8 months between the closing of the application and the decision. Now they have a one step application in which they reduced the time line to 4.5 months. But there are often informal communications between agencies and companies to check the eligibility of projects. They have assessed the cost of running a common call. After that they have decided to distribute the tasks among the partners and not to concentrate them to one or two agencies which will take in charge all the process. Each country is polyvalent which prevents problems in case a central country decides to leave the programme
- Infrastructure: The access to research infrastructure is crucial and they are very expansive. It is very important that universities, research centers and firms cooperate to share the infrastructure. At the beginning of their life cycle, the start-ups live their 3-4 first years in university labs to share their infrastructure. With international cooperation the SMEs can get access to research infrastructure which would not exist in the country. In ETB, projects are sometimes organized around RI, giving access to them, but research infrastructure is less a target but a collateral benefit of sharing knowledge

5.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives an assessment on the achievements of the exercise.

Critical Mass of Funding budgets:

- Coverage of relevant countries: 12 Europeans countries of Regions are participating to ETB and to the calls. Some important actors are missing. For instance the UK: the biotech landscape and the capital market structure have a different structure in the UK than in the rest of Europe. Biotech companies do not rely on public funds: there is no public programme devoted to sustain the biotech industry in the UK. The same is true in Switzerland. Sweden and Norway are also absent. Denmark preferred to participate to Eurostars: http://www.eurostars-eureka.eu/what.do. In ETB-PRO France is also missing..
- Each call has a pot of about 20M€ in ETB1 and 30M€ in ETB-PRO
- Each partner should have a national or regional programme with funding which could contribute to the common call. They should all contribute at the same level. Without programme they cannot participate.
- They use the system of virtual pot
- Some partners adapted their programme to ETB: the NL decided to set up the rules of their national programme according to functioning of ETB (so there is only one proposal to be made by companies, and not two, ie one to ETB one to the national agency, as in most of the countries). Italy adapted in terms of flexibility
- ETB is also a cooperation between agencies and after this experience they could launch bilateral programmes.

Critical Mass of beneficiaries:

- The missing (UK, FR, CH, SW, NO, DK) countries have strong SMEs which could be important research partners in the calls.
- Around 55 to 60% of the European biotech SMEs have the possibility to apply to ETB funds. If we take into account the landscape of public funding (UK has no public programme supporting biotech SMEs) in Europe, than ETB covers a larger proportion of European companies having the possibility to apply to ETB
- The average number of beneficiaries in a consortium is three, which corresponds to the target of having small partnerships for SMEs
- The eligible actors are: universities, research organizations, large companies and SMEs. So far, ETB has launched 5 calls and supported 99 projects with total project costs of €174 Mio. The ETB 5th call with the participation of 12 countries and regions and a minimal total funding budget of about € 30 Mio has closed on February 1st, 2010. Some 244 SMEs together with 78 academic organizations and 5 large industries are currently benefiting from ETB funding to perform transnational projects. This means an SME participation of about 74%. ETB projects might be funded in any biotech sector (red, green, white/grey, blue). However, the majority of the funded ETB projects are in the Health biotech sector (83%; red biotech) followed by Agro-Food (10%; green biotech). Industrial biotech (white/grey) and marine biotech (blue) applications account together for 7%.
- Over the six calls there are almost no recurrent beneficiaries. The main reason is that the candidates are SMEs that are too small to be able to run two ETB projects at the same time.
- The projects are monitored by the funding agencies. ETB has sent a questionnaire to beneficiaries with mainly qualitative indicators. It is possible to have this information because of confidential business data and some agencies have strict rules about confidential issues.

Author's comment: Even if important actors are missing, overall ETB seems to cover a large part of the European biotech industry. Since 2006 it launched every year a call with high common pots. It seems that they succeeded in changing the SMEs mentality and induce them to cooperate internationally

5.2.4 Critical Mass objective achievement

In this section, we report how respondents assess the achievement of objectives and, secondly, how the level of achievement can be judged based on output indicators.

The first aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

There are answers from fours respondents (four partners). They are slightly different from above and there seems to be an agreement around three objectives.

- "to address a Socio-technological challenge" (2 partners)
- "To secure a certain level of competences in a very new area, i.e. for prospective reasons": (3 partners)
- "to reach excellence" (1 partner)
- "to reach self-sustained dynamics in the development of the area" (3 partners): the critical mass for that project is to create an environment in which transnational cooperation in

biotech for SMEs is possible. And for them ETB allowed “A "critical mass", covering more than 55% of European biotech enterprises”. If a country or region approaches ETB to become a member of ETB, this would mean that ETB has reached a CM to become an attractor. The fact that countries are willing to enter ETB could be an indicator that the CM has been reached. In some way, as between ETB1 and ETB-PRO some new countries entered we could consider that some level of CM has been achieved

For the other types of CM it is too early because very few results are available: the first funded projects ended only recently.

Secondly, we look at the list of output indicators as reported by the interviewees. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can now do a check which CM type is best supported by the output profiles given by the interviewees.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New/improved processes, products and services; licensing, spin-off companies; patents, other IPR, access to new markets	Indicated by all respondents, Important indicators are witnesses.	*Coherent with CM objectives*
Address scientific challenge	Scientific publications, additional researchers, creation and access to new research fields	Indicated by only one or two respondents.	*Has not been identified explicitly as an objective in section 2.1. and 2.4*
Securing a level of competence (defensive)	*n.a. according to section 2.1*		
Securing a level of competence (prospective)	Scientific publications, additional researchers, creation and access to new research fields, patent citation, step forward a new stage of development	Indicated by only one or two respondents – except step forward a new stage of development witnessed for 3 participants	
Reach Excellence	Scientific publications, patents,.	Most important indicators are witnessed / expected, but two of them only by one respondent.	*Has been identified only by one participant*
Self-sustained dynamics	Patents, Scientific publications, additional researchers, networking, increasing number of actors active in the field, increasing cooperation, increasing number of actors in the field	The most important indicators are witnessed	

Overall, addressing a socio-technological challenge and self-sustained dynamics seem to be supported by the indicators. Securing a level of prospective competence is less obvious even if the participants claim that they have made a step forwards this direction.

According to the author’s assessment, most important among these objectives seems to be self sustained dynamics, as it has been identified from the beginning by all participants as one of the major objectives. This is also clear from the fact that they rate themselves the respective indicators of CM very high (networking, cooperation, increasing number of actors, enhanced science-industry linkages etc.).

As there has been show there is a progress in respect to self sustained dynamics, even if they agree that the field has not yet reached a level of sustainability. Addressing a socio-technological challenge is supported by the indicators but less by the participants and the reverse is true for securing a level of competence. Overall this EN tends to do progress in reaching important objectives of CM.

5.2.5 Factors relevant for achievement or non-achievement

While we describe in section 2.1 possibly relevant environmental conditions and in section 2.2 possibly relevant determinants (activities), we arrive in sections 2.3 and 2.4 at the results and level of achievement. In this section we draw a first analytical conclusion from this case study about which of the above mentioned factors (either environmental conditions or something related to ERA-NET activities) appears to be a relevant factor for (non-)achievement of CM. The statements are based on the indicators or other evidence from the interviews in this case study.

- **Clear objectives shared by all the participants**: ETB covers a niche: to fund applied research and development projects, in small international consortia, for young and small biotech companies in some European countries. All the participants had the same vision
- **Number of calls**: The main aim of ETB is to setup calls. They launched six calls and funded more than 300 beneficiaries, mainly SMEs (244). A UK consulting company reported that in 2005/2006 there were 2400 biotech companies in EU. This would mean that in less than 5 years ETB would have funded 10% of them, knowing that they cover 55% of the whole sector.
- **Small scaled consortia**: the average size of a funded project is two to three beneficiaries, which is consistent with the need of SMEs. Some development projects in the biotech do not need large consortium.
- **Participating countries need to have a national or regional programmes supporting the calls**: without such a programme there is no possibility to participate to ETB
- **Participation of leading countries in the biotech field**: even if some major actors are missing and thus potential contributing beneficiaries, an important range of good European R&D leaders with complementary competences are potentially able to set up valuable consortia in the field.

5.3 Conclusions

In terms of level of EU public R&D funding, it can be concluded that Biotech is a field largely funded by EU and national programmes, but they are either inappropriate to the SMEs needs (too large consortia) or they do not allow for international cooperation (mainly national programmes). In terms of coordination and organization, it is clear that the main gap that ETB intends to fulfill is allowing biotech SMEs to engage in international cooperation agreements with a size adapted to their needs. The field is very development oriented and for these issues there is often no need to build up large consortia. Finally, as regards competition issues, it emerges that Biotech is a highly competitive area and ETB is a means for SMEs to strengthen their competitiveness. International cooperation allows them to become more visible.

6 The ERA-NET iMERA

6.1 Introduction

iMERA was preceded by the FP5 project MERA and, in general, by EURAMET (European Association of National Metrology Institutes) that was already active in the 1980s as EUROMET. All EUROMET countries were invited to take part in this initiative. The idea of iMERA was, and still is, through iMERA Plus and EMRP to implement the European Research Area on metrology.
iMERA was a peculiar ERA-NET, being an horizontal in the sense that metrology underpins all scientific areas. The main aim of iMERA is the creation of R&D collaboration mechanisms among the community of EU metrology institutes. Specifically, the integration of this community and their programmes has been a central goal of iMERA.
The objective of iMERA was to coordinate and integrate activities of the metrology institutes across Europe. The aim is to involve 27 participants (plus associate countries) soon, though democratic participation within the few countries at the outset was strong. The wide participation in Article 185 is due to such democratic representation: countries' representatives do not feel they are losing sovereignty. In addition, through iMERA, an attempt has been made to involve all the European Ministries (usually Ministry of Industry) in the ERA-NET.

Research field: Metrology
Sector: Industrial technology and SME
Overlaps with other ERA-NETs: Because of the horizontal nature of metrology, maybe some overlaps in other themes / ERA-NETs may happen, but always related to metrology applied to that theme.

Duration: 45 months in FP6: April 2005 – May 2009, iMERA Plus in FP7 from June 2007– May 2012.
EC funding: € 3 998 774 (FP6, Source: CORDIS).

The ERANET consisted of 20 Members from 14 countries at the outset:
Coordinator: United Kingdom: National Physical Laboratory (NPL)
Partners:

34. Czech Republic: Czech Metrology Institute (CMI)
35. Czech Republic: Nuclear Physics Institute of the ASCR VVI (COSMT/NPI ASCR)
36. Denmark: Danish Fundamental Metrology Ltd (DFM)
37. European Union: European Commission - Joint Research Centre (EC-JRC)
38. Finland: Centre for Metrology and Accreditation (MiKES)
39. France: National Laboratory of Metrology and Testing (LNE)
40. Germany: Federal Ministry of Economics and Technology (BMWi)
41. Germany: National Metrology Institute (PTB)
42. Italy: National Institute of Metrological Research (NRIM)
43. Netherlands: Ministry of Economic Affairs (MinEZ/MinEA)
44. Netherlands: Van Swinden Laboratorium B.V. (NMI)
45. Norway: Norwegian Metrology Service (JV)
46. Poland: Central Office of Measures (GUM)
47. Slovakia: Slovak Institute of Metrology (SMU)
48. Slovakia: Slovak Office of Standards Metrology and Testing (UNMS SR)

49. Slovenia: Metrology Institute of the Republic of Slovenia (MIRS)
50. Sweden: Technical Research Institute of Sweden (SP)
51. Switzerland: Swiss Federal Office of Metrology (METAS)
52. United Kingdom: Department of Trade and Industry (DTI)

Entries / Exits: Almost all EUROMET countries showed an interest and, if possible, participated in iMERA. Exceptions were Austria, Spain and Turkey. However, these countries are now part of EMRP and iMERA Plus. The reasons why they weren't able to participate orginally are that Austria did not originally have a national metrology programme and that Spain and Turkey faced organisational barriers.

This report is based on the following sources:

- Basic information from CORDIS
- Responses of the coordinator and four participants to CRIMASS online survey (*status of 28 January 2011*).
- In-depth interviews with the coordinator (NPL, UK,) and the following partners: METAS / Switzerland, SP / Sweden
- No Beneficiaries' answers available (no joint calls) - Under FP6 iMERA only one joint call was launched in 2005, and it was not public. It was considered a pilot and only participants themselves could be beneficiaries of this call.

6.2 Critical Mass analysis

6.2.1 External factors and policy objectives related to Critical Mass

We understand "Critical Mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field. This can be done first according to what the interviewees indicated as the ERA-NET's objectives.

Answer from Coordinator:

To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.), the main rationale for participation in this ERA-NET was indicated as a combination of three goals: learning from funders, sharing information between funders in other countries, and creating and supporting transnational projects in a field which requires transnational cooperation. In fact, iMERA makes clear its objectives in the Description of Work of the ERA-NET itself, as:

1. Systematic exchange of information and best practice for metrological research programme owners and national metrology institutes.
2. Strategic activities, such as identify the activities best addressed collaboratively, enable European countries with emerging metrology programmes to participate successfully in joint research activities, etc.
3. Joint activities, such as interact with European stakeholders to develop and execute a systematic and on-going dedicated European metrological foresight process, improve the mobility of European metrologists, in particular for countries with emerging research programmes.
4. Transnational activities

5. Realisation of the ERA in metrology through Article 169 of the Treaty
6. Dissemination, Governance and Consortium Management, such as ensure that stakeholders are appropriately informed as the project progresses so that they may input with a full understanding of the issues.

Answers from participants:

- To address socio-technological challenge (2)
- To address scientific challenge (3)
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (2)
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (1)
- To reach excellence (4)
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (3)

From these answers, there is no clear evidence of a defined objective common to all partners. The most widely mentioned objectives of the ERA-NET are the type 6 objective "self-sustained dynamics" together with the type 5 objective "excellence". In fact, the objective of iMERA was to coordinate and integrate activities of the metrology institutes across Europe implementing the European Research Area in metrology, as well as to spread knowledge of metrology and its applications.

Policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

As a field of research, metrology is mature and directly connected to existing market, even if it is not fully understood. In fact, the research area is already partially explored but a lot of research is still going on and an increasing number of researchers/labs are becoming involved. In short, the field is being investigated by a lot of competing actors with no clear leader. Even within the metrology community, an improvement in reciprocal knowledge is needed, not in terms of R&D undertaken, where it is known who is doing what, but rather in the way the metrology infrastructure functions in each country. The research area absolutely requires a large physical infrastructure that is only available in one (the EU) or very few places. Metrology is heavily connected to ongoing research activities in other fields, both in terms of the users of the results from this research and in terms of the supplier of the results to those activities. It requires the development of geographically concentrated resources, at the moment identified as National Metrology Institutes and Designated Institutes[4]. But metrology faces a "primordial" dilemma: have only one metrology institute at European level or have a network of National Metrology Institutes? For the moment, taking advantage of the ERA-NET initiative, the idea is to have a network and reinforce it, though there is always a tendency to centralise functions and, especially, facilities.

World leaders in this field: the EU, the US and Japan, both at the research and market levels.

The descriptions make the following type of objective clear:

"To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.)" implementing the ERA for metrology, especially if most participants' main rationale for participating was to create and support transnational projects in a field which requires transnational cooperation.

[4] Private research centres that perform metrology research

6.2.2 Determinants of Critical Mass

The activity profile of an ERA-NET (activities related and not related to R&D) should give a rough idea of the kind of achievements that can be expected. iMERA activities clearly point to the CM objective of reaching self-sustained dynamics in the development of the area. Also the Critical Mass approach based on joint calls, and on involved beneficiaries, is not applicable to this ERA-NET.

- All iMERA activities led to the implementation of iMERA Plus and EMRP (European Metrology Research Programme). As already stated, coordination activities aim at putting together all the metrology institutes in Europe.
- Dissemination activities through workshops and conferences aim at sharing information about what metrology is.
- In addition, through iMERA, an attempt has been made to involve all the European Ministries (usually Ministry of Industry) in the ERA-NET.
- Main FP6 activities were the non-R&D ones, especially meetings for coordination, seminars and conferences. An important activity has been a scoping study, aimed at better understanding the scope of metrology and how different countries prioritise the subject. Under FP6 the European Metrology Research Programme was prepared, though launched only under FP7.
- Under FP6 iMERA only launched one joint call in 2005, and it was not public. It was considered a pilot, and only participants themselves could be beneficiaries of this call. It was launched mainly as a "challenge", to test the difficulties in running joint calls. However, running joint calls was not the key activity of FP6 iMERA, while it has been a more crucial activity under FP7.

6.2.3 Components of Critical Mass

This section gives an overview of the different types of resources which have been pooled by ERA-NET activities. It also gives an initial qualitative assessment on the achievements of the exercise.

Relevant countries: At the beginning – under FP5 – the number of institutes was lower (less than ten), while at the moment the participants' number has increased to 20 (from 14 EU countries). Some of them (Turkey, Spain) weren't ready to join the ERA-NET initiative due to administrative reasons that now, in iMERA Plus and in EMRP, have been resolved. In general, the number of participants is considered adequate.

Critical Mass of Funding budgets: No joint calls have been launched, or better only one pilot joint call not open for beneficiaries other than the participants themselves has been launched. iMERA's activities are mainly dedicated to:

- to consolidate the EUROMET association, now a legal entity recognised and registered as EURAMET, an association of public utility under German law;
- to prepare iMERA Plus in which launching joint calls;
- to prepare the EMRP, launched in 2009. European Metrology Research Programme (EMRP) is a partnership between 16 EU Member states (Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, The Netherlands, Portugal, Republic of Slovakia, Slovenia, Spain, Sweden, United Kingdom), two EFTA (Switzerland and Norway) countries and Turkey. It aims to join relevant European national programmes and activities

to accelerate the development of vital research capabilities that, on the one hand, supports competitiveness and, on the other hand, provides an infrastructure that supports EU policies. The Joint Programme is based on former Article 169 (now article 185) of the European treaty. The European Commission (EC) will co-fund this Joint Programme through Article 169 - the most advanced instrument for the integration of European Research. The overall budget for the programme is 400 million Euro, co-funded at 50% by the EC and 50% by the countries participating in the programme. The EMRP will play an important part in the construction of the wider European Research Area.

➔ Author's comment: Although no joint calls were launched in iMERA, a step forward towards a self-sustained dynamic has been made, through the establishment of EUROMET, and all subsequent FP7 activities.

Critical Mass of Infrastructures:

All transnational activities have been effective, except for sharing facilities which has not been so effective, especially because of the "short" duration of iMERA initiative. All iMERA participants started to make an inventory of all facilities in the network in a catalogue, but they didn't start to really share their facilities. This is one of the long term goals, especially for huge facilities (e.g. accelerator), through which an attempt is made to create a centre of excellence for the use of those facilities, perhaps concentrated in one place (e.g. the accelerator is at PTB - DE premises). One of the next steps, perhaps in EMRP II, is to have coordinated services (in the line of a coordinated R&D programme) regulated by a "traceability agreement" in order to have good offers on the market and sell those services.

6.2.4 Critical Mass objective achievement

The second element to consider is the direct responses of the interviewees, i.e. their own assessment of which of the objectives related to CM they are witnessing or expecting any progress from. It should be noted that from desk research, it seems that Critical Mass has been achieved because iMERA passed all ERA-NET steps towards (former) art. 169, passing by a program (EMRP) and by an ERA-NET plus experience.

Answer from the coordinator: the assessment given by the coordinator includes other types of Critical Mass objectives, such as type 1 to address socio-technological challenge and type 2 to address scientific challenge. The achievement of Critical Mass has been considered as a long-term objective of the ERA-NET, to be reached through the integration of metrology actors across the EU. In fact, the demand for metrology keeps growing and that brings the need for integration. Steps forward have been made in this direction and, though Critical Mass has not been fully achieved, the establishment of an EU collaborative Research Program has been seen as a success.

Also, participants have witnessed some progress for certain objectives. Some responses here are partly different from the initial answers (see 2.1). The responses are listed below.

- To address socio-technological challenge (3, coordinator and 2 partner)
- To address scientific challenge (5, coordinator and 4 partners)
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (1 partner)
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (4 partners)
- To reach excellence (4 partners)

- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (3, coordinator and 2 partners)

The resulting synthesis seems to be that the coordinator and participants have different views on what the ERA-Net should have achieved. The participants seem to have the priority of addressing scientific challenge and securing a certain level of competencies for prospective reasons, while the coordinator keeps a strong focus on reaching self-sustained dynamics.

Thirdly, we analyze the list of output indicators as reported by the interviewees and survey respondents. We have mapped the output indicators to each of the different types of CM objectives in a preliminary fashion, and can now check to see which CM objective type is best supported by the output profiles given by respondents and interviewees.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New processes, products and services (2); Standards, norms (3); creation, access to new research fields (2).	The most important indicators are witnessed / supposed, although not by everybody. Other, less important indicators mostly not witnessed.	
Address scientific challenge	Scientific publications (5); creation, access to new research fields (4).	The most important indicators are witnessed / supposed, by all. Less important indicators not witnessed	
Securing a level of competence (defensive)	Scientific publications (5); improved processes, products and services (3); new research contracts (3).	The most important indicators are witnessed / supposed, by all. One important indicator (number of patents) not witnessed, maybe because of the nature of the sector. Less important indicators not witnessed	
Securing a level of competence (prospective)	Scientific publications (5); new research contracts (3).	Almost all most important indicators witnessed. Some less important indicators (creation, access to new research fields) expected by most of participants.	*In the author's view less applicable as an objective of its own for this ERA-NET.*
Reach Excellence	Scientific publications (5); market share of the EU / world business sector (1).	Scientific publications expected by all, while market share only by one participant. Important indicators such as improved position in international ranking and patents not witnessed / expected	
Self-sustained dynamics	Scientific publications (5); additional researchers (2); networking (3); increasing number of actors active in the field (1).	Except for patents, the most important indicators are witnessed / expected. Most indicators of minor importance are witnessed by more than one respondent.	

So, overall, while one can concede progress with respect to reaching self-sustained dynamics, the other objective related to critical mass has not (yet) been realized: a lot of effort has been focused on launching FP7 actions such iMERA Plus and EMRP. As stated by one participant, "An important achievement of iMERA has been that it has led to a **higher legitimacy of national metrology programmes**. In other words, the visibility of metrology in European countries is now higher, and this leads to new R&D opportunities in other fields (being metrology, as already said, a cross-sectoral science)."

6.2.5 Factors relevant for achievement or non-achievement

We can determine from what has been said so far and from additional statements of the interviewees the factors relevant for the described achievements and the reasons for non-achievement (being either environmental conditions for the ERA-NET or the activities of the ERA-NET itself). From the iMERA case study, we find the following set of explanations:

- The main factor for such a step forward has been the fact that priorities across the EU have now been aligned: all EU metrology institutes are now onboard and are working in the same direction.
- Basically, the step forward to reaching critical mass has been made thanks to this coordination effort, completed in iMERA, of the national metrology programmes participating to the ERA-NET initiative.
- However, given the specificity of the ERA-NET, no specific type of Critical Mass was individuated. The importance of coordination among countries was emphasized, both as an objective and as an achievement, but all types of Critical Mass in our questions were considered at the same level. It is too early to evaluate the level of achievement of Critical Mass.

6.3 Conclusions

At the European level, the national metrology programmes' size reflects the power of the countries involved. The UK and Germany are the biggest players. The respective contributions to EMRP reflects this situation as well. Considering the total amount of the EMRP programme contributions (400 M€, 50% EC + 50% in-kind contribution), 75% is given by Germany, the UK, France and Italy. Specifically, Germany owns 32% of the entire programme. Switzerland is a middle player, similar to Sweden (341.000 € annual funding); Poland and Estonia are minor players (60.000 € / year).

A huge effort has been made to establish the ERA-NET because iMERA was quite different from usual ERANETS in scope (since it is an horizontal one). It was, however, in line with ERA-NET criteria at that time. Nowadays, an ERA-NET like this would encounter more difficulties in being funded. The reason is that iMERA was largely a non R&D ERA-NET, devoted to aligning national programmes on metrology and to developing, as a result, a European programme as a guideline and closer integration of national R&D activities.

Beneficiaries are not identifiable because, until now, ERA-NET participants have tended to fund themselves due their nature of National Metrology Institutes, being owners and beneficiaries of the National Metrology programme. But, as has already been mentioned, there is huge competition between the idea of centralising metrology at the European level rather than keeping the network alive.

The coherence between iMERA activities and the national metrology programme is good, especially considering that the main reason for realising iMERA was to avoid duplicating the same activities in different countries. However, the ERA-NET's complexity is a bit higher than in national programmes. A clear comparison is difficult to make, since under FP6 iMERA, no joint call was launched. With regard to overlap with other ERA-NETs, it is very low because the others are more vertical and focused in one scientific field only. Because of the horizontal nature of metrology, it is

possible that some overlaps with other themes / ERA-NETs may happen but will always be related to metrology's application to that theme.

7 The MANUNET ERA-NET

7.1 Introduction

MANUNET is a joint effort between EU regions sharing a view of Europe's future that will demonstrate the relevance of manufacturing as one of the fundamentals of the Economy of Knowledge. It is estimated that in total 75% of the EU GDP and 70% of employment in Europe is related to manufacturing. Fortunately, Europe is in a privileged position in some of the key manufacturing sectors, those with high technology demands, and therefore, the sustainability of European manufacturing is the success in R&D for manufacturing. Manufacturing activities tend to concentrate in regional poles, speeding up the value added chains, products, services and knowledge trading. Therefore, Regions are naturally suited to respond to these sector needs. A number of these Regions devote R&D programmes to respond to short-to-medium term industrial needs, complementing the longer term focus of national and European programmes. These R&D activities are the most fragmented layer of European research, with little coordination from Agencies, and therefore, there is a large opportunity to contribute to ERA. Manufacturing research must also be understood from the perspective of European Zones that are highly increasing their capacities due to delocalisation from the West.

MANUNET was launched under the 6th EU Framework Programme in April 2006 in order to guide SMES towards ERA by providing yearly calls for proposals and assistance to achieve high success rates of applications and facilitate projects close to industry and market. It came to a close in October 2010, but MANUNET II under the 7th EU Framework Programme is currently under preparation. MANUNET's strategic objectives have been:

- Execution of common or joint calls for proposals for research in manufacturing, open to 21 European Regions, as the key contribution from MANUNET to ERA.
- Durable cooperation by means of the execution of the MANUNET model of yearly coordinated calls, in an evolutionary path that will also benefit from the extended opportunities in FP7.
- Coordination with other European R&D support initiatives in Manufacturing, from the Technology Platforms side (emphasis in MANUFUTURE) and other instruments (ERA-NETs, MNP area of FP6/7).
- Mutual enrichment of the regional/national R&D support programmes by fruitful interchange of experiences.
- Enlargement of the ERA-Net-Consortium, creating a notable platform to impact on European manufacturing research.

Under FP6 MANUNET, four joint calls have been launched (annually, in 2007, 2008, 2009 and 2010), while the fifth one has just been closed in January 2011. In terms of non-R&D activities, so far three annual MANUNET conferences have been conducted (2007 in Bilbao, 2009 in Florence and 2010 in San Sebastian).

With regard to its geographical distribution, MANUNET is widely distributed in Europe, especially when considering the associate partners as well. At the moment, MANUNET includes 21 contractor partners, representing 13 regions (Basque Country, Catalonia, East Netherlands, Emilia Romagna, Flanders, Lower Austria, Navarra, North Rhein Westfalia, Northern Ireland, Piedmont, Tuscany, Wallonia and Western Greece) and five countries (Estonia, Germany, Romania, Slovak

Republic, Slovenia), plus 10 extra associated partners (France, Switzerland, Asturias, Lower Silesia, Aragon, East Midlands, Provence, Styria, Tampere and Valencia).
MANUNET has a strong industrial characterisation, with a cross-sectoral focus on the broad definition of manufacturing.

Research fields: manufacturing industry.
Sector: industrial technologies.
Overlaps with other ERA-Nets: some overlap with ETRANET, MNT-ERA.NET and MATERA.
Duration: 4 years under FP6: April 2006 – October 2010.
EC funding: € 2 696 220 (FP6, Source: CORDIS).

Excluding associated partners, 21 members from 12 countries are currently in MANUNET. 15 of them were members since the beginning of the ERA-NET (in 2006, highlighted in bold).
Coordinator: Basque Agency for the promotion of international Research, Development and Innovation, Spain
Partners:

1. Austria: Government of Lower Austria, Department of Economy, Tourism and Technology
2. **Belgium: Institute for Promotion of Innovation by Science and Technology in Flanders**
3. Belgium: Ministry of the Walloon Region, Directorate general for Technologies, Research and Energy
4. **Estonia: Enterprise Estonia**
5. **Germany: Zentrum für Innovation und Technik in Northrhein-Westfalen GmbH**
6. **Germany: Ministry of Innovation, Sciences, Research and Innovation of Northrhein Westfalia**
7. Germany: PTKA, Project Management Agency Forschungszentrum Karlsruhe
8. **Greece: Region of Western Greece**
9. **Italy: Sviluppo Italia Toscana SCPA**
10. **Italy: ASTER S. Cons. p. a.**
11. Italy: Industry Direction of Piedmont Region
12. **Netherlands: Development Agency East Netherlands**
13. **Romania: National Centre for Programme Management**
14. **Slovak Republic: Ministry of Education of the Slovak Republic**
15. **Slovak Republic: Slovak University of Technology**
16. **Slovenia: Ministry of Higher Education, Science and Technology**
17. **Spain: Basque Government - Industry, Trade and Tourism Department**
18. **Spain: Department of Industry and Technology, Trade and Labour of Navarra**
19. Spain: ACC1Ó, Agència de Suport a l'Empresa Catalana
20. UK: INVESTNI, Invest Northern Ireland

This report is based on the following sources:

- Basic information from CORDIS and MANUNET website.
- Responses of coordinator and eight participants to CRIMASS online survey (*status of 31st January 2011*).
- In-depth interviews with the coordinator (INNOBASQUE, Spain) and the following participants: EAS (Estonia), PTKA (Germany).
- No Beneficiaries answers available.

7.2 Critical Mass analysis

7.2.1 External factors and policy objectives related to Critical Mass

We understand "Critical Mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field. This can be done first according to what the interviewees indicated as the ERA-NET's objectives.

Answers from Coordinator:

- "to reach excellence".

Answers from Participants:

- To address socio-technological challenge (3)
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (2)
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (2)
- To reach excellence (3)
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (5)

Among respondents' answers there is no clear evidence of a predominant objective of MANUNET ERA-NET. While for the coordinator the fifth objective ("excellence") is clearly relevant, for other respondents the most selected was the sixth ("self-sustained dynamics"). The first answer might reflect a general aim of participants to improve the quality of project applicants through ERA-NET activities. In fact, among the rationales for participating in MANUNET, the most selected was "creating and supporting transnational projects in a field which requires transnational cooperation". Similarly, this rationale confirms the importance of the sixth objective, where the involvement of key actors in the field is the prominent activity.

Also MANUNET, like other ERA-NETs (e.g. MNT and MATERA), has a strong industrial nature. Not by chance, therefore, the type of research is purely development oriented and an objective like the second ("scientific challenge") is deemed irrelevant by all respondents.

Policy objectives related to "Critical Mass" can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

Since MANUNET is characterised by a specific geographical issue – regional based participation – but also by a very wide sectoral approach – that is manufacturing on the whole – it is not easy to address the environmental conditions of the scientific area. The joint calls budget has funded very different projects, whose specificity was simply being related to R&D in manufacturing.

Nevertheless, it can be made clear that the main motivation for the creation of MANUNET has been the need to support manufacturing in Europe starting from a regional point of view. Among the ERA-NETs already existing, in fact, the coordinator together with other active participants recognized that a purely manufacturing ERA-NET was missing. While mapping EU countries with the aim of creating such a manufacturing ERA-NET, a second need emerged: that is the lack of a regionally based one. From the merging of these two issues, MANUNET was created.

Together with the coordinator, other regions were also very active before the start of MANUNET, with the specific aim of involving the highest possible number of associate partners among EU regions. Some administrative problems led to the partial participation of important manufacturing

regions in the ERA-NET. It was in fact too difficult to convince the representatives of some of these to participate.

In terms of global competition, manufacturing on the whole is considered a mature area of research, dominated by few key actors coming from very well known geographical areas. Luckily, Europe has a long tradition in manufacturing R&D and the sector on the whole still represents the most important economic activity in Europe. Nevertheless, competition is arising, especially with two sets of countries from Asia: first, a well established group of industrialised countries such as Japan, Korea and Taiwan; then, the fast growing economies of China and India, where pure manufacturing is now supported by increasing investment in R&D facilities.

The objective of MANUNET, therefore, is to support the investment in R&D for the manufacturing sector in Europe. According to this, the choice of basing such investment on the regional level is strongly consistent with the sixth objective ("self-sustained dynamics"), as individuated by many respondents in the Critical Mass survey. MANUNET project applicants are in fact asked to be top players in manufacturing research at the global level.

7.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give first indication on what kind of achievements can be expected.

MANUNET has launched five joint calls so far, where companies, universities and research centres could be project applicants. Thanks to the first 3 calls (years 2007, 2008 and 2009) 271 applications were made; 88 of these were successful and got funding, with about 56 million euro of national or regional funding in total and 234 SMEs were involved. It has been confirmed by respondents and interviewees that the features of joint calls executed by MANUNET are especially attracting newcomers and SMEs because of the transparent procedures and low administrative efforts required. All calls in general generated many transnational projects with small consortia on a low administrative barrier, accelerating funding decisions on the national or regional level. The acceptance rates were generally very good.

MANUNET joint call projects present an average size of about three partners from at least two countries; an average budget ranging from 70,000 to 3,000,000; a most frequent budget of 500,000 euro; and 36 months as the average length. Selected beneficiaries are equally distributed among industries, SMEs and universities, with a low predominance of SMEs.

Besides joint calls, in MANUNET some non-R&D activities have been performed: some internal studies and three conferences.

These issues, anyway, do not provide relevant information about the type of Critical Mass most appropriate for the MANUNET ERA-NET.

7.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives a first qualitative assessment on Critical Mass achievement.

The coordination and integration efforts needed for trust building in MANUNET have been quite high. The need for an exchange of philosophy among the participants was individuated from the beginning in order to increase knowledge in a reciprocal way. Unfortunately, the degree of commitment among countries has varied significantly. Especially at the beginning, when the

novelty of the ERA-NET scheme was causing some administrative problems, not all the partners were putting the same effort into MANUNET activities.
Positive results have been achieved regardless. They are exemplified by two main achievements: the number of participants has increased from the beginning of MANUNET; the ERA-NET is going on under the 7th Framework Programme in MANUNET II, where all MANUNET partners are still present in addition to new ones.
During the second year of MANUNET (2007), there has already been a first approach for cooperation with other ERA-NETs: some ETRANET participants joined the MANUNET 2007 call; some contacts were starting with participants in the joint MNT-MATERA call. Since MANUNET is covering horizontal topics, the overlap with ETRANET (with regard to ICT for manufacturing) and MNT-MATERA (on nanotechnologies and materials science) has become quite obvious. Therefore, the need for coordination and integration beyond MANUNET borders has been underlined. The coordinator has then worked to avoid this overlap.
Components of Critical Mass in funding programmes:

- Coverage of relevant countries: not enough, since at least two important manufacturing countries are missing (France and the UK).
- Number of participants: the geographical coverage in terms of numbers is quite good. It is also quite balanced, since participants come from all EU corners.
- Joint calls have been launched regularly (one per year, 5 in total in the 2007-2011 period), being a positive achievement. Furthermore, almost one hundred projects have already been funded.
- The extension of MANUNET to the FP7 period testifies the will of giving continuity to the efforts in supporting a regional-based R&D in manufacturing.

➔ Author's comment: joint calls' activity has been the most important activity of MANUNET for the achievement of Critical Mass. This effort is clearly visible in the number of joint calls launched. The integration of EU R&D programmes is still limited, though steps forward have already been made. The need for integrating MANUNET with other ERA-NET activities has been individuated, though key activities in this regard are still not evident.

7.2.4 Critical Mass objective achievement

In this section the direct responses of the interviewees are reported, i.e. their own assessment on which of the objectives related to Critical Mass they are witnessing or expecting any progress.

Answer from coordinator: steps have been made forward with respect to the first two types of objectives: type 1 ("socio-technological challenge") and type 2 ("scientific challenge"). This represents quite a big discrepancy from the objectives set "ex ante", since both were not taken into consideration by the coordinator and "scientific challenge" was completely absent in respondents' aims. Also participants see some progress for all the objectives, confirming a certain degree of ambiguity between their aims and their achievements, as reported below:

- To address socio-technological challenge (coordinator and 1 participant).
- To address scientific challenge (coordinator and 2 participants).
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (1 participant).
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (3 participants).

- To reach excellence (3 participants).
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (4 participants).

The cross sectoral and horizontal focus of MANUNET might have played a key role in the self-assessment of respondents' achievement. In some cases, in fact, participants have witnessed an improvement in their scientific output – therefore also in the direction of "scientific challenge" improvements – while in other cases the networking and science-industry linkages might have suggested the advancement in terms of "self-sustained dynamics".

Given such ambiguity in the self-assessment, it is necessary to map the list of output indicators as reported by the interviewees and survey respondents. The output indicators are grouped according to the different types of Critical Mass objectives, as can be seen in the table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New processes, products and services; Access to new markets.	Some of the most important indicators are witnessed, but there is no common agreement	
Address scientific challenge	Scientific publications, creation of access to new research fields	Some of the most important indicators are witnessed, but there is no common agreement	
Securing a level of competence (defensive)	Scientific publications, patents, improved processes etc., new research contracts.	The most important indicator (improved processes) is the only one on which there is clear agreement; on the contrary, patents are never witnessed	*In the author's view this confirms the industrial nature of the ERA-NET and cannot be considered a key factor*
Securing a level of competence (prospective)	Scientific publications, new research contracts.	The most important indicators are not clearly witnessed	
Reach Excellence	Scientific publications, improved position in international ranking, patents	The most important indicators are not clearly witnessed	*In the author's view this confirms both the industrial (and not scientific) nature of the ERA-NET*
Self-sustained dynamics	Scientific publications, additional researchers, networking, increasing number of actors	Almost all most important indicators witnessed, with a full agreement on the enhanced science-industry linkages	*In the author's view this is the clearest signal of achievement*

Overall, self-sustained dynamics (type 6) appears to be the only type of achievement supported by the empirical evidence. In all other cases, in fact, there is a strong discrepancy among indicators belonging to the same Critical Mass typology. This is the case for types 3, 4 and 5, where patents and scientific publications should be witnessed together with other indicators (as improved processes and products, or step forward a new stage of development). Instead, while the latter indicators are witnessed by almost all respondents, patents are witnessed only by the coordinator, and publications are reported in less than half cases.

As a conclusion, the **achievement of the type 6 Critical Mass objective seems to be the most relevant in the case of the MANUNET ERA-NET. It has been selected as an objective by five out of eight respondents; four of them declare that advancements in its achievement have been made; furthermore, output indicators support their statements. It should be noted, however,**

that coordinator's answer is slightly different. Regardless, the interview with the coordinator itself has confirmed that clear advancements have been made in this direction, mainly referring to the increase of key actors in the field as well as their strongly improved internationalisation as a major outcome of participation in MANUNET calls.

7.2.5 Factors relevant for achievement or non-achievement

We can determine from what has been said so far and from additional statements of the interviewees the factors relevant for the described achievements and the reasons for non-achievement. From the MANUNET case study, we find the following set of explanations:

- **Coordinator's engagement in the ERA-NET**:
  - The coordinator of MANUNET has played a key role in involving participants from all over Europe and building trust within the network.
- **Number and regularity of joint transnational activities**:
  - Given the applied research / industrial type of ERA-NET, the regularity of joint transnational activities (yearly joint calls, almost yearly conferences) appears to be a positive factor in the achievement of Critical Mass.
- **Increased internationalisation of the projects:**
  - International cooperation has led project applicants to open up their activities to cross-border collaboration. Thanks to the ERA-NET, this approach has been replicated even in activities outside MANUNET, extending the cooperation with foreign pioneers in the field;
  - Subsequently, such internationalisation of R&D cooperation has led project participants to extend their market horizon.

7.3 Conclusions

Since the whole manufacturing sector has a very wide scope, it is not easy to assess whether the level of public R&D funding is adequate or not. The case of MANUNET has shown that there exists a very dispersed funding of manufacturing R&D all over the EU, especially when including that at both the national and regional levels.

Therefore, the centrality of coordination and integration activities stands as the main goal for MANUNET. The coordinator has put much effort in trying to involve as many EU actors as possible in the ERA-NET; this objective has been partially achieved, though some large countries are still missing in MANUNET.

The overall coordination in MANUNET has been performed mainly through discussion on the best way to launch joint transnational calls. Similarly, yearly conferences have been used to exchange information on best practices at the EU level. The degree of commitment of single countries in this exchange, however, has varied significantly.

The cross-sectoral approach of MANUNET – in which single projects can span very different topics – has led to a certain degree of overlap with other ERA-NETs (especially ETRANET, MNT and MATERA). Aside from the attempt to avoid duplication, no particular strategic decision has been taken in order to integrate MANUNET activities with those of the previously mentioned ERA-NETs or even with other ERANETs. This might mean that, to a certain extent, MANUNET's approach is not leading to a higher level of integration and a lower level of competition among research

projects in the EU. The size of this ERA-NET is increasing, but its scope is still too wide to avoid duplication and overlap among EU R&D programmes.

8 The ERA-NET MARIFISH

8.1 Introduction

MariFish intends to establish a network comprising Europe's most important marine fisheries research funding bodies. The aim is to improve the coordination, planning and funding of research, and to make the most of ICES expertise. MariFish activities include exchanging information on current national research and development programmes being run by the partners; finding ways to improve research planning and procurement by pooling knowledge; and identifying areas of existing collaboration at regional, European and international level. The project also aims to compare and analyse national research programmes to identify areas of common interest, gaps in research and areas of duplication. This will help the partners develop and commission shared research activities in up to five pilot areas. The long-term aim is to identify the strategic and innovative requirements of fisheries research over the next ten years, before developing jointly funded programmes to meet those needs. One of MariFish's objectives is to identify research topics that will be particularly suitable for coordination at European level and will bring added benefits to the ERA. Work here will include reporting on specific problems in the EU's fisheries management and research programmes. Research issues with an EU dimension will then be identified within existing national and international programmes. These findings will feed into the development of the project's five pilot research areas, ensuring that national and European needs are both given due consideration by MariFish.

Research Fields: Marine Fisheries Research
Sector : Environment
Other ERA-Nets in related fields: AMPERA, BONUS, MARINERA, IWRM.Net-CA; SEAS-ERA in FP7
Type of research: Basic and Applied research
Duration: 5 years in FP6: Jan. 2006 – Jan. 2011
EC funding: BONUS : €2 977 070 (FP6, Source: CORDIS)

18 partners : 17 from 15 EC members and 1 from an associate state :
Coordinator: Department for Environment, Food and Rural Affairs (Defra), Fisheries Directorate, UK
Partners:
• The Research Council of Norway, Norway
• The Federal Ministry of Consumer Protection, Food and Agriculture, Germany
• The Federal Research Centre for Fisheries, Germany
• Ministry of Agriculture, Nature and Food Quality, Department of Fisheries, The Netherlands
• The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning, Sweden
• The Icelandic Centre for Research, Iceland
• French Research Institute for the Exploitation of the Sea, France
• Ministry of Food, Agriculture and Fisheries, Directorate for Food, Fisheries and Agri Business, Denmark
• Ministry of Agriculture, Rural Development and Fisheries, Portugal
• Morski Instytut Rybacki wGdyni/Sea Fisheries Institute in Gdynia, Poland

• Research Promotion Foundation, Cyprus
• General Secretariat for Research and Technology, Ministry of Development, Greece
• Marine Institute, Ireland
• Ministry of the Flemish Government Centre for Agricultural Research, Sea Fisheries Department, Belgium
• Scottish Executive, Fisheries Research Services, UK
• Ministry of Education and Science, Spain
• Ministry of Science and Information Society Technologies, Poland

Entries / Exits: none reported

This report is based on the following sources:

- Basic information from CORDIS
- Information from the MARIFISH website
- Responses of coordinator and one participant to CRIMASS online survey (*status of 31 January 2011*).
- In-depth interviews with the coordinator DEFRA (UK), IFREMER (France), the Instituto Español de Oceanografía - attached to the Ministry of Science and Technology (Spain), and the Danish Food Industry Agency (DFIA) - Ministry of Food, Agriculture and Fisheries (Denmark).
- 23 Beneficiaries identified (ie participation to a project), contacted for the S2 survey.

8.2 Critical Mass analysis

8.2.1 External factors and policy objectives related to Critical Mass

In order to understand the rationales underlying the set up of MARIFISH as well as its organization characteristics, it is useful to bear in mind the environmental characteristics of the research field. From e-surevy and interviews, it is possible to briefly summarized them as follow.

The area of research related to MARIFISH :
- is already partly explored but with a lot of research going on and an increasing number of researchers/labs involved
- is dominated by a few key actors
- is partly dependant on large physical Infrastructure only available in one or a very few places, and available in Europe
- requires more intangible type of infrastructure such as database, archive etc, but also physical mobile ones such as vessels
- is not essentially requiring some local concentration of actors (academic-agencies-companies) around localized research infrastructure and close face-to-face interactions favoured by geographic proximity
- is heavily connected to ongoing research activities in other fields, largely as user of the results from those research
- is backed up by international organisations among which predominates the ICES- International Council for the Exploration of the Seas
- is directly connected to existing market

The interviews allowed to precise some of these points.

• In fishery, there are a lot of research / scientific questions which are common to all countries and all regions. For instance in North sea, there are a lot of resources, but fishers do not always respect quotas and frontiers, then studies are needed to be able to improve the monitoring and management of these resources.

• One key issue in the field of MARIFISH is that data gathering and management, modelling, monitoring at European level is not the simple add up of data gathering and management, modelling and monitoring at regional or national level : when the whole picture is taken into account, other models have to be designed and used, more and different variables have to be included etc to take into account global and/or interaction phenomena. Each regional and each country simply cannot achieved that level separately. So clearly, the European level (and here the MARIFISH level) is a threshold.

• In fishery science, it is estimated that EC and EU countries expend 160 M € a year for research, among which 30/40% to "pure" research and 60-70% to survey and monitoring activities. So it was quite natural to go to ERA-Net in order to better coordinate this second aspect in particular.

• In fishery research, ICES (International Council for the Exploration of the Sea- http://www.ices.dk/) is the main body; Europe is clearly in the world league in this field, for instance in fishering gears (technical innovation, electronic surveillance …) however, there are some "lacks"' in the research fields for instance fishery economics and tools for management (eg evaluation of quotas and estimation of the evolution of the fleet structure combined with the size of fish population).

• Before Marifish, there were indeed a lot of cooperation between research institutes, but not so much between the funding bodies, ie the Ministries. There has been previous partial collaboration (Baltic countries, or through UNO groups for instance on tuna or salmon, or thanks to the annual meeting in Copenhagen of the International Consortia for fishery stock assessment, which provides estimation of current and forecast stocks) but nothing of the type of Marifish.

• In contrast, fisheries are also like a closed world, that open up only slowly. Traditionally, the fisheries industry is not really involved in science, except from some inventory and monitoring activities. But it depends on the countries as well, some being more advanced in that respect. But the key point here is the lack of resources and the poor financial situation of this sector. It is considered that public support equals to 100% of fisheries turnover, and if one includes social securities and pensions burden, the public general support to the sector is 300% of the turnover.

• Fish population are to be analyzed and managed at the level of sea region, and sometimes inter-sea regions, for instance in the case of salmon or red tuna. The community of research on fisheries and acquaculture then increasingly felt the need to work together. Some programme managers were in contact with the EC DG Fisheries which advised to go to ERA-Net. The other countries agreed to go on since although some aspects are regional and some other are national, there are a lot of common matters too. Previously, the community of research already existed, with one of the main way being the CIEM (ICES International Council for the Exploration of the Sea) that was

created before 1900, groups more than 1500 researchers, and yearly provides some recommandations about the fish resources management taking into account fish population evolution. A concerted action was launched in 2004-06, that led to the creation of the EFARO (www.efaro.eu) an association of the Director of European research teams/centers working in the field of fisheries and acquaculture. So when ERA-Nets were launched, there were interested. Also, having funding agencies causes an orientation towards target-oriented research; it is the case in MARIFISH, where it is in relation with managers of fisheries resources who often ask for advice on the management.

To sum up, MARIFISH is in a field which characteristics are
- global issues,
- interaction between local phenomena and then between neighbouring regions,
- importance of "not-pure-research" activities related to monitoring and data related processes
- economic challenges, regarding not only sector (fisheries) but also food sector in general
- strong relation with environmental issues.
- research very scattered, and mostly carried out on a national basis, with a little coordination.
- research infrastructures are required in some areas, mainly consisting on the one hand on fleet of vessels for inventory, and monitoring. Then sharing time between experiences is crucial; and on the other hand, data base and data management infrastructure.
- fisheries is also a very nation-based activities, and thus policy decision in that field is also nation-based.

The objective of MARIFISH is to strengthen the links between marine fisheries science and fisheries management. More broadly, the long term aim is to be able to manage stock of fishing resources in a sustainable way, focusing on "that research which provides evidence for managers for the development of strategies for sustainable fisheries, including links with acquaculture, set within the ecosystem based principle".
The objectives are not precise in quantitative terms, but activities are organized around the general objective, and long term perspective is adopted. Participants acknowledge that there is a huge potential, for instance it is estimated that the UK production could triple with a better management of resources.

Defining objectives required an agreement between the participants on choosing the sea region as level of work, and to agree on the sea regions where there is a need for common vision and collaborative management

In turn, this motivates the realization of a detailed inventory of research activities and scope of fisheries management in order to identify where there is a need to set up common activites and possibly set up critical mass. This is particularly done through the 5 programmes launched as a MARIFISH activity, see below.
The mapping of programmes and research activities and of fundings (present and future) has helped to identify and choose the niche in which MARIFISH could bring added value :
- on areas which are not funded by existing programmes
- on areas where the existing programmes (be they national or FP ones) could be complemented by other more focused ones, by correcting this or adjusting that, in order to enhance the whole set.

2. Consequences in terms of critical mass related objectives

It is clear from what preceeds that "to address socio-technological or research challenge" is the main critical mass related objective. This is confirmed by all interviews.

From the beginning, the strategic topics have been choosen in one of the first meeting : the development of indicators for fishery management, when stock have recovered a satisfying level, allowing to monitor that level in the future and at least stay with the same level of resources for the far future.

Given the scattered character of the research and the need to combine different sub-fields to address those issues, the critical mass type "to reach self-sustained dynamics in the development of the area" is also considered as important. 3 out of 4 interviewees agreed on this point as well as all respondents to the e-survey.

8.2.2 Determinants of Critical Mass

The determinants of the critical mass are the participants, the activities that have been conducted during the ERA-Net, the way those participants were interacting and conducting these activities, all this deterining the conditions in which resources are pooled together and possibly reach a critical mass level.

Countries and participants

They have been listed in the introduction. The only important missing participant is Italy. This is due to a fragmentation of responsabilities at policy and programme level in the field of fishery. However, some Italian regions have been invited and are attending some MF meetings. Another critical fact has been that Germany has reduced its activity in MARIFISH because of a disagreement with the EC in terms of budget. But in general, the number of participants is considered good because it is not too big.

Activities

The activities are clearly structured through the workpackage breakdown. However, some activities have been added during the life of MARIFISH. "preparatory" activities are as follows.

a) study on improving interaction/communication between fisheries managers and researchers, with the help of scientific communication specialist, including interviews over 6 countries on best practices and main problems

b) study on knowledge management in fisheries science and policy

both a) and b) activities were not originally planned; they were carried out with the help of specialist in the fields but not at all specialist in fisheries. Reports and communication materials are available on the MF website.

c) study carried out to understand the importance of non-traditionally associated disciplines for the development of fisheries science, and to try to identify more precisely future key fields of research. In particular, fisheries science has been dominated for long by biologist (growth rate, movements etc of fishing resources), but economics and socio-economics, while important, have not been so much related to the previous field. MARIFISH wanted to know which fields of research were explored and should be explored in the future in social sciences; they looked at more than 800 existing studies in the fields of economics, sociology, anthropology, law, public administration and other social sciences, , and put the conclusion on the marifish website in a way that facilitate

identification of fields and researchers. The aim of the database is to provide an overview of, and access to, the increasing volume of research in this area, particularly with reference to European fisheries.
d) survey on existing collaborations between participants at regional, European and international levels were analyzed in WP3.
e) survey on national research programmes and projects, compiled in a publicly available data base (with a dedicated research tool including sorting and filtering etc), in order to identify synergies, gaps, actors etc. It shows how the 160 M € spent in Europe are allocated.

In addition, 5 Research programmes have been set up. After having identified the most important topics in marine fisheries management, five topics have been selected to be developed into collaborative research programmes by a group of interested countries. Two programmes focus on a particular region and three (one is delayed) focus on a particular issue since this gives all partners a chance to participate. Some programmes aim to collaborate without providing any new research funding and some will use additional funding to strategically link the programmes together. Research budgets will be retained by individual partners; a jointly funded programme will be undertaken (see below), but these programmes are jointly managed by the partners. For those programmes, there are some funds for organizing the workshops, and between sessions, people are working in their own teams with their own money. Sometimes there are some bilateral work, using other sources of money (for instance thesis associating Fra and NL on one theme). For each workshop, people are asked to present something new and orginal, and this is the "scientific interest" that lead people and make them participate. The funding for this workshop activities is about 600-700 K€ in total; but at least workshop need to be funded and to take place quite regularly, otherwise things will slowly fade up. There is a MOU between the different organisations participating to each programme, including possibility to work beyond MARIFISH, so on a legal/institutional point of view the framework is in place.
The programmes are:
Regional Case Study – Developing the Ecosystem Approach in The Channel – led by IFREMER, France
Regional Case Study – The Mediterranean – Fish Habitats and Trophic Interactions – led by GSRT, Greece
Thematic programme - Reducing discards (ie fishes rejected to the sea by the fishers) – led by Defra, UK
Thematic programme - Influence of climate on small pelagic fish biology, distribution and population dynamics– led by IEO (MICINN), Spain

Those 4 programmes are almost finished, and the 5th programme (Influence of climate on fish biology and population dynamics) has apparently not been developed so much, notably because since it was launched, EC has launched in parrallel other FP programme on the same topic. On the one hand, it shows that the choice of the topic was relevant, but in practical terms, interested teams are going to those programmes and not to the MARIFISH one. The programme is now more oriented towards indicators on coastal aspects.

Finally, a joint call has been issued on fishery management indicators. Denmark, Iceland, France, Cyprus, Greece, Netherlands, Norway, Spain and United Kingdom had agreed to fund research on the development of operational fisheries management indicators that will help fishery managers

to develop long-term management plans. The rule is virtual common pot (each research organisation should submit a bid for research up to but not exceeding the amount indicated by the relevant national funding organisation). The projects should regroup 3 of more research organisations, with project up to 3 years. €4.13m were available from countries fundings. 6 proposals have been made, 3 projects have been selected:
REPROdUCE: Understanding recruitment processes using coupled biophysical models of the pelagic ecosystem.
BADMINTON: Bycatch and discards: management indicators, trends and location.
DEFINELT: Developing fisheries management indicators and targets.
The 3 projects will end in 2012.

Overlap with other ERA-Nets:
Up to now, there is no real overlaps with other ERA-Nets, and even only a few interactions.

ERA-Net activities and national /regional programmes:
The coordination with the national and regional programmes is apparently quite relevant, but goes along different ways (funding set aside, real strategic coordination, clear disctinction between line of research runned on a national and on an internatinal basis, ect).

8.2.3 Components of Critical Mass

The components of the critical mass are the resources (in terms of quantity and quality) pooled for research by the beneficiaries in the context of the projects that are selected. This section gives an overview on the different types of resources which have been pooled by ERA-Net activities.

Number of projects : 3
Number of beneficiaries (ie participations) : 23 identified
Number of beneficiaries (ie organisations): 16 (among which some of the participants of MARIFISH)
Average number of beneficaries (ie participations) per project : 8
Average MARIFISH budget per project : 1 253 050 €
Average duration of project : 48 months
Nature of beneficiaries : exclusively university labs / research organisation labs (no companies identified)

As regards **critical mass of funds**, the total budget provided through the MariFish 'common pot' amounts to €3,759,149. The Danish partner is contributing an additional €513,000, the Greek partner €463,000, and the French partner €293,000 through co-financing agreements with their participating research institutes. Indeed, the MARIFISH funds corresponds to a very small share of all research expenditure sin fisheries (approx. 0.5% of the 160 M€ per year, see above). But MARIFISH has targeted a niche in terms of research, and thus critical mass funding components cannot be assessed by this simple calculation.
As regards **critical mass of projects**, the number of projects cannot be seen as significative of a critical mass in simple quantitative terms. Fairly high technological project are looked for; commercial risk is not relevant here. But in general, projects are quite similar to the national ones, in terms of risk, scientific excellence, but could be seen as potentially bringing more value for money, thanks to the pooling of specialized competences. But some participants underlines that

the positive effect of MARIFISH has been the creation of orginal projects that otherwise would not have been done. REPRODUCE has been cited as an example. Within this project, a collaboration with a U.S. University has been set and this is a strongly original effect of the ERA-NET. The "economics" side of the bids was under-represented at a high scientific level; most proposals have more environment-related aspects than economics.
As regards **critical mass of beneficiaries**, one can note that there are only university and research labs, agencies, a few consultants, no company : the industry does not fund this kind of research (it is marine and not maritime, for which more industry funds are available). There was only 6 proposals, but including the right people the right groups on the right topics, and given constraints (number of partners, virtual pot) the best partners possible are present.

8.2.4 Critical Mass objective achievement

In this section, we summarized on how the the profile of activities described above is informative on the achievement of CM, but also on how respondents assess the achievement of objectives and, secondly, how the level of achievement can be judged based on output indicators.

• The **profile of activities** runned by the ERA-Net gives a first indication of the achievement of the critical mass objective. The orientation of the activities, and the focus on indicqtors adopted for the call clearly point the progress towards the CM objective of addressing socio-technological challenges. The apparently important activities runned under the 5 programmes can be seen as preparatory work for securing the scientific background necessary to a relevant definition of such challenges, and the type/scope of answers that research can provide. They also denote the attempt to trigger a self-sustained dynamics in the development of the are, at this stage mostly limited to research community.

• The second aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

There are answers from four respondents (four partners). They are slightly different from above and there seems to be an agreement around three objectives.

- “to address a Socio-technological or scientific challenge” (2 partners)
The interviewees underline the importance of cooperation for bringing together complementary competences, knowledge, data or resources, insisting on the qualitative aspect of it. For instance, in the Channel eco-system are modifed by fishering, tourism, stone exacavation, etc. Then it is needed to interact with managers in order to have a common view on the main obstacles, which could be at two levels. First, at the level of the sudies on biodiversity, study on the deep water, of the different zones at different depth etc. This is the level of the research, mostly academic one. This raise no problems, studies are open to the different parties. The other level is the data on fishing activities, which revealed problems, and administrative obstacles. This a very sensitive point, and each country (or even each body within a country) used to keep proprietary data. France and UK will reach an agrrement on this.
A different example is provided in the Mediterranean case. Each country is organizing inventory and monitoring campaigns, but there is a need to integrate and mutualize national data bases in order to set up long term series of observation on fundamental variety, taking into the impact of invasion by non-Mediterranean species, of the climate change and of the fisheries activities. But in

this case, the "locking" is on the academic research side : researchers want to keep a exclusive access to their data in order to publish first. if researchers wants to keep exclusivity, it may play against the set up of critical mass. Critical mass also goes through the openess of information and the sharing of knowledge, given the cumulative nature of knowledge creation. There is not a strong need of having very up-to-date data since the evolution analyzed are in quite long term trend of evolution. A proposed solution is then to leave a priority access to the scientist then to open it to a "club" of those contributing to the campaign, and then to make them public.
On pelagic fish , the problem is that there are some peaks of population but in a very irregular way : it is different each year and for each specy. Spain, Gree, It, Fr, Croatia work together in order to map the flows and understand these phenomenon, given various environment parameters, using vessels, satellites etc sources of information. Now the maps of the Mediterranean sea have been released. In terms of critical mass, how long would it have taken if only one country had to do the full job ? ten years ? more ? at which cost ?
Another example is provided by the trophic network (or food-chain). A workshop has been organizedin Barcelona in 2010, notably about such models. These models are used in many studies for many different objectives, but there are plenty of them, and still some (useful ?) refinements and development of new ones. The aim of the workshop what to determine and agree on which model to choose, given the objectives of the study and of the different parameters, and in order to standardize the choice and procedures of the calibration parameters. In this case, if more and more people are using the models and are chosing them according to the standard defined, then critical mass could be achieved (some non EC members have already shown interest); there is a lot of communication work to be done to reach this however, especially towards ministries and agencies.
Another example is in the case of the bass fish. There are actually 5 varieties of bass, which causes some problems of management. The problem is that the varieties are travelling across various regions of the sea, if only one variety is fished in each region, then it will disappear; this can only be solved by coordination and cooperation between managers and researchers on the different varieties, but there is no need to have 1000 researchers on each variety !

In many fields related to MARIFISH the critical mass has two aspects.
First there is an issue of scarcity of competences: for instance there is a need of one genetician specialist in a given species, but not more. On pelagic fish for instance, there are 2-3 real specialists working in France, 3-4 in Germany, 5-6 in Spain etc. The number of researchers is then very small, and the critical mass is about 15 persons in Europe, who can be brought together during 2 or 3 workshops. But this number may vary :
- some domains are changing, following a standard evolution of science
- the social demand is also changing: before, inventory could be made species by species, now more and more, combined inventories have to be made, including different species, and adding to that effects on/of envirionment, disgard etc, plus the climate and environmental changes that made species moves from one zone to the other. Then multidisciplinarity is required, with fisheries science mixed with biodiversity, environment, climate disciplines etc.

Second, there is a need of data, for inventory, monitoring, data collection etc, so there is a need of resources for that (vessels, people, satellites etc, and access time). How many vessels and campaigns are required to to do that ? and how much money ? MARIFISH helps to understand

what is existing, how these resources are organized, and how they could be optimized. There is an EC funding to support that, but it depends on the required rate of sampling.

- "to secure a certain level of competences in a quite traditional area, i.e. for defensive reason (2 partners)
there is a good example of "defensive" with "systematic" and naturalist in the field of biodiversity. One or two specialists per species is enough but we need them. For instance now, for silt sworm, there are only some left in UK and Poland. Some emerging countries are now trying to specialized in that field, accumulating huge collection and data on this (a new research work worldwide repartition ?).
- "to secure a certain level of competences in a very new area, i.e. for prospective reasons" (1 partner)
there are examples in bio-computer science, or genetics, but not so much in MARIFISH. Another example is when looking at the frontiers between disciplines where breakthrough are often appearing (ex genomic of population included in food-cahin models). But for this objective prospective, other programmes are very relevant, notably ANR in France and in some fields, FP at EC level.

- "to reach self-sustained dynamics in the development of the area" (1 partner)
at least there is a dynamics created among the participants, attested by the participation to the programme workshop. Also, MARIFISH was the first time that ministires and agencies of all countries were really working together at that level.

• As regards **outputs and impacts**, direct answers from interviewees, as well as information from e-survey and first projects reports bring some further elements. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can do a check which CM type is best supported by the output profiles given by the interviewees.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-techn. Challenge		The most important indicators are not witnessed / supposed. only few of other, less important indicators are witnessed.	*observations on output do not support the achievement of this objective*
Address scientific challenge	Scientific publications, creation of access to new research fields	The most important indicators are witnessed / supposed. Less important indicator not witnessed	*In author's view more applicable than type 1 (socio-technological challenge), seen as a first step towards the ultimate type 1 objective*
Securing a level of competence (defensive)	Scientific publications, new research contracts.	Some important as well as less important indicators witnessed	*apparent agreement by respondents.*
Securing a level of competence (prospective)	*Similar to defensive CM, but logically, it can only be one of them, although there is some specificic case (data monitoring) that may be seen as "in-between"*		
Reach Excellence	Scientific publications.	Except for scientific publications, no important indicators are witnessed / expected	*Quite clear agreements between respondents*
Self-	Scientific publications,	Except for patents, the most important	*In author's view, a step towards*

sustained dynamics	additional researchers, networking, increasing number of researchers	indicators are witnessed / expected. Most indicators of minor importance are witnessed	*objective type 1*

Addressing a research challenge, securing competence for defensive reasons and to a lesser extent self-sustained dynamics seem to be supported by the indicators.

According to the author's assessment, those three objectives seem to be the most important among these objectives, with a slight preeminence of research challenges, as it has been identified from the beginning by all participants as one of the major objectives.

There is a apparent coherence between the different sources of information about the type of critical mass objectives as well as the about the level of achievement. As compared to the objective, it seems that despite a focus on practical end user orientation of the research (ie indicators for a better management of fisheries resources), MARIFISH is more about addressing research challenges as a basis for solving social issues in the future than directly coping with socio-technological challenge. And for this purpose, the size of the critical mass may be quite small, depending on the sub-field. Also, the issue of maintenance of certain competences appears more important in fact than it was in the objective. But it is too early to really assess whether all those dimensions of critical mass objectives has really been achieved, beyond specific cases.

8.2.5 Factors relevant for achievement or non-achievement

Based on the preceeding analysis, the main factors relevant for the achievement or non achievement of the critical mass are the following.

• In general, anyway, MARIFISH has been useful to share knowledge about the different EU experiences in fisheries, and to increase the information about best practices in other countries. It also open the mind to possible future participation of foreign actors to national programmes, and also led to some bilateral collaborations. The fact of having countries active in different seas has been seen as an advantage to compare different needs. On the other side, each country has its own priority and that arises some punctual difficulty in the coordination mechanisms.

• The alignement between MARIFISH approach and the strategy of research in the marine field which is already largely strategically driven by EC (with EC strategy document, ex the move towards regional approaches and the need of cross-disciplinary collaborations); there is nothing specifically new brought through MARIFISH, but MARIFISH is one piece of the puzzle.

• The implication of some of the leading organisation in research in marine field.

• The perspective open by the functionning of some of the programmes set up in MARIFISH, coordinating research agenda in a flexible way, as a sort of alternative or complementary way beside the more classical "calls" (but requiring a strong implication and a good positioning of the coordinator, as well as a basic but permanent funding).

The factors of uncertainty (rather than real hampering factors) are related to different aspects.

• the possible divergence of countries / organisation visions about their common interest in terms of research, and in terms of relative importance of marine research. When different institutions from different countries are collaborating, there is always a risk of having different perspectives, different visions. For instance in some countries, fisheries is a very small sector, less than 1% of

GDP; it is also a very small sector in research, but conversely everybody knows everybody. Differences in sea regions could be at stake here, despite the similary of some of the research issues

• the lack of financial backup from the fisheries industry, which is not in a flourishing economic situation and is traditionally not so open to marine research; beyond the funding aspect, this could also lead to a difficulty to attract the interest of the sector, despite all the effort made by the participants during MARIFISH

• the present economic crisis, which has already disturbed the funding set up of the projects and that may cause some severe cuts in the research budegt of some key members

• the future involvement of the coordinator, which is one of the parameter of the decision regarding the follow up of MARIFISH (new ERA-Net, merger under SEAS-ERA with a risk that fisheries become "lost" in this overarching ERA-Net on sea, "light" institutional device, etc)

8.3 Conclusions

EU fundings and MARIFISH fundings are quite small as compared to the overall sector, which is itself of a decreasing importance in the economy. Any evaluation of an adequate level of funding has to be on very specific issues or sub-fields of research.

In terms of coordination and organization, it emerges that these are favoured by the alignement to the general EC marine strategy; however, national interest are still very important especially as regards fisheries activities. At research level, coordination level is likely increasing.

Finally, competition is very localized in specific area of research, ie in niche. But in a lot of respect, there is a need of more cooperation rather than increased competition, for instance for sharing data, archives and monitoring/experimental equipments.

9 The MARTEC ERA-NET

9.1 Introduction

MARTEC is a partnership of 19 European ministries and funding organisations responsible for funding RTD in maritime technologies from 15 countries. All together these countries represent more than 90 % of the gross tonnage (GT) of shipbuilding output in Europe which shows that this network already covers the EU key players in that field.
MARTEC focuses on funding issues and is planning to create a lasting network of key agencies that will improve the way in which maritime technologies research is managed and developed. This network will produce a strategy for future research funding, and will encourage the development of transnational programmes of activity able to reflect the needs of the maritime industry.
One of the core objectives is to create an appropriate response to the increasing role and dominance of especially East Asian competition, and secure knowledge, innovation, profitability and employment in this traditionally European sector (with strategic technologies), by concentrating on highly advanced areas, such as environmental protection, safety and security, the use of IT, and the development of innovative products at a coordinated EU level.

Research field: Maritime technology: shipbuilding, off shore etc.
Sector: Industrial technology
Overlaps with other ERA-NETs: Some other ERA-NETs have a limited degree of overlap with MARTEC from thematic perspective: such as EUROPOLAR on polar technologies, the energy and environment oriented Eranets and TRANSPORT. The specific angle on maritime technologies and its industry focus sets MARTEC apart from the other Eranets and gives it very distinct features. MARTEC keeps a close cooperation with the Technology Platform WATERBORNE.

Duration: 36 months in FP6: June – May 2009, MARTEC II is being under negotiation at the moment.
EC funding: € 2086549 (FP6, Source: CORDIS).

Full MARTEC ERA-NET participants

53. Federal Ministry of Economics and Technology (BMWi, DE)
54. Project Management Juelich (PtJ, DE) Co-ordinator
55. Research Council of Norway (RCN, NO)
56. Ministry for Ecology, Energy, Sustainable Development and the Sea (MEEDDM, FR)
57. Centre d'Etudes Techniques Maritimes et Fluviales (CETMEF, FR)
58. Association of Finnish Marine Industries (AFMI, FI)
59. National Technology Agency (Tekes, FI)
60. National Centre for Research and Development (NCBiR, PL)
61. INNOVAMAR (INNOVA, ES)
62. Danish Maritime Authority (DMA, DK)
63. Ministry for Economic Affairs (MinEZ, NL)
64. Universitatea Dunarea de Jos Din Galati (UDJG, RO)
65. Swedish Maritime Administration (SMA, SE)

Entries / Exits: Certain important players will join MARTEC II such as Italy. The consortium will be extended to include most major EU players in the field of Maritime industries.

Initially only 1 call was planned, but due to the success of this call in 2008 further calls were launched. MARTEC has now launched 3 joint calls (1 pilot and two joint calls) on horizontal themes of maritime technologies, having a bottom-up approach from a thematic point of view. It has also realised a common database of experts for evaluation.
The first pilot call in 2008 was done in two stages and attracted 15 proposals of which 4 were selected. The later calls abandoned the 2 stage approach, and evaluated all in one go. The 2009 call was of very high level, leading to 7 of the 11 proposals being selected. The last call of 2010 also attracted 11 proposals but only selected 3-4 (process not yet finished).
The transnational and central evaluation procedure has been established, although the eligibility check is done at national level. The total cycle from launching the call to starting the project takes a year. Even though the overall evaluation procedure is centrally executed, it is followed by national procedures to implement its results.
MARTEC has developed a good practice or international evaluation: database of the evaluators; common procedures for internationally evaluating projects; guidelines on how to sustain the ERA-NET after the EC funds.
Monitoring and reporting in MARTEC I is done at a national level. Common procedures will be established in MARTEC II.
In MARTEC II the partnership will be extended to 28 European ministries and funding organisations responsible for funding RTD in maritime technologies from 24 countries.

This report is based on the following sources:

- Basic information from CORDIS
- Responses of coordinator and four participants to CRIMASS online survey (*status of 28 January 2011*).
- In-depth interviews with the coordinator Juelich/DE and the following partners: Innovamar/Spain, Tekes/Finland and Universitatea Dunarea de Jos Din Galati/Romania
- Other sources, web and material provided by the coordinator

9.2 Critical Mass analysis

9.2.1 External factors and policy objectives related to Critical Mass

We understand "Critical Mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field. This can be done first according to what the interviewees indicated as the ERA-NET's objectives.

MARTEC is strongly driven by the need of the EU Maritime industry to remain competitive with its counterparts around the world.

The European maritime sector is facing the challenges of strong competition from technologically advanced and overall lower labor cost countries in the East Asia (South Korea, Singapore, Japan, Taiwan, China etc). Due to its strategic value for the EU in general and for the larger ship building nations (such as for instance Germany, Poland, France, Italy, Norway) in particular.

The key CM driver for all participants is:

- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons

As a second layer of CM objectives the participants highlighted:

- To reach excellence, in particular in core technology areas covered by MARTEC such as Off Shore and safety and sustainability issues
- To reach self sustained dynamics
- To address a socio-technological challenge

Policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

Leading countries in the EU are Germany, Italy, France and the Scandinavian countries; MARTEC I was strongly focused on the northern European countries; MARTEC II tries to strike a better balance by for instance including Italy.

The EU is strong in certain areas as off shore but at the same time do not want to lose its position in more traditional areas and retain knowledge, employment and market share in key strategic areas.

Strong drivers for the sector and particularly in the EU and the US are environmental impact concerns as well as safety and security issues.

9.2.2 Determinants of Critical Mass

The activity profile MARTEC is centred around industrial/applied research. Almost all activities are RTD driven, apart from surrounding promotional and coordination activities. The activities clearly point to the CM objective of securing a certain level of competences in a quite traditional area by strengthening international (EU) cooperation development. The bulk of activities are in the 3 joint calls which have delivered 37 proposal and 15 funded projects. On average these projects have 5-6 partners. Average funding of projects is in the area of 1 Million Euro.

MARTEC has defined its success criteria as follows:

- Development of a sustainable network and partnership of funding agencies and ministries
- Participation in calls.
- Sufficient number of relevant/good applications to calls.
- Sufficient number of projects started and allocation of funds.
- Commitment of national authorities by the means of funding.
- Increased cooperation between participants from different countries.
- TP Waterborne will see MARTEC as one way to implement their strategic agenda and will give its benefits back to MARTEC.
- Carrying out of recommended joint activities other than calls.

MARTEC II will take the developments further and aims to:

- Reduce duplication of research efforts on maritime technologies across Europe
- Identify and respond to gaps in research activities
- Create the necessary critical mass in research in certain areas
- Improve the cost-effectiveness of current research programmes

- Develop common standards for the prioritisation, commissioning and evaluation of research proposals
- Improve access to research results across Europe
- Contribute to the competitiveness of the European maritime industry
- Promote international cooperation

9.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-NET activities. It also gives a first qualitative assessment on the achievements of the exercise.

Relevant countries: MARTEC I included 19 participants (including observers) across 19 countries. Even though this was considered strong and covered the vast majority of of the gross tonnage (GT) of shipbuilding output in Europe, it still lacked some important players as Italy. In Martec II these players join the consortium, amounting the GT to 95% of shipbuilding output in Europe.

Critical Mass of Funding budgets: Several joint calls have been launched. MARTEC has a virtual common budget, but participants are in reality funded on a national basis and with the corresponding national funds from the virtual budget. In MARTEC I the annual budget amounts to 60 M Euro, in MARTEC II this will be raised to 176 M EURO annually. It has to be noted that the budget cycles at national and the MARTEC calls do not coincide which often creates delays and other issues, whereby often no optimal use can be made of the funding available.

Even though there was a virtual central budget, some of the Member States could not participate due to lack of national funding. This means that for smaller and less resource rich partners, MARTEC does not create additional mass.

Critical Mass of Infrastructures: Infrastructure for testing ship building and off shore developments are expensive and not available in all countries. MARTEC plays an important role in providing testing and laboratory infrastructures for the different partners.

9.2.4 Critical Mass objective achievement

The second aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

There are answers from 6 respondents (the coordinator and 5 partners). They are slightly different from each other, possibly along the lines of the more and less 'important' EU Maritime industry countries.

The key challenge reportedly most achieved is reaching excellence (3 partners and the coordinator), even though this was not the primary objective. The international cooperation especially benefits the smaller maritime countries to reach better results, to learn from experiences and advanced RTD, and use (test) facilities to further developments. In some cases specialised knowledge also spills over from smaller countries to the larger countries.

Achievement of the original core objective to secure a certain level of competences in a quite traditional area, i.e. for defensive reasons is reported by the coordinator and 1 partner. This corresponds to the interviews. Especially the larger countries aim for this challenge.

The third challenge achieved (according to the questionnaire) is to reach self-sustained dynamics in the development of the area, some of the countries reported increased national RTD budgets as a result of MARTEC, or even a new budget line for Maritime RTD.

Interestingly enough the respondents report better achievement in addressing a scientific challenge than in addressing a socio-technological challenge, whereas the latter is a more prominent objective to the participants.

• As regards **outputs and impacts**, direct answers from interviewees, as well as information from the participants and coordinators survey bring some further elements. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can do a check which CM type is best supported by the output profiles given by the interviewees.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-techn. Challenge	Enhanced Science industry linkages, new or improved processes, products and services, change in employment levels, Step forward,	The most important indicators are not witnessed / supposed. only few of other, less important indicators are witnessed.	*apparent agreement by respondents*
Address scientific challenge	creation of access to new research fields	Quite weak only less important indicator not witnessed	
Securing a level of competence (defensive)	Market share EU/globally, changes in employment level, increase of innovative firms, increase number of actors	Mostly important indicators witnessed	*apparent agreement by respondents.*
Reach Excellence	Nnetworking, new and improved products and processes	Except for scientific publications, no important indicators are witnessed / expected	*apparent agreement by respondents*
Self-sustained dynamics	Networking, increasing number of actors, Enhanced science industry linkages	The most important indicators are witnessed / expected. Most indicators of minor importance are witnessed	*apparent agreement by respondents*

Securing a level of competence and addressing a socio technological challenge seem most supported, followed by reaching excellence (although the indicators are weaker than the perception of the interviewees and respondents) and self sustained dynamics.

There is a fair level of coherence between the different sources of information about the type of critical mass objectives as well as the about the level of achievement, even though one can distinguish the responses and goals of the larger maritime players from those of the smaller maritime players . MARTEC is in the end clearly about competitiveness of the EU Maritime sector, therefore part of the CM objectives aim at securing levels of competence, while at the same time aiming for excellence in areas where the EU can outperform its competitors from especially the far east.

9.2.5 Factors relevant for achievement or non-achievement

Based on the interviews and feedback through the questionnaires we can conclude that the main factors for achievement of CM are coming from defragmenting the EU RTD and markets in the maritime sector, and focussing on core areas in which the EU is strong and leads the market and the science, while broadening the base for players and actors in the field, including 'smaller' maritime nations and allowing them to use facilities and transferring knowledge. MARTEC is in a position of creating the required CM also due to the fact that it represents the major institution of countries that make up the vast majority (95%) of the shipbuilding industry in the EU.

While MARTEC contributes to the CM goals there are barriers to achieving the goals. The major barriers stem from the fragmentation of the EU market, and include the high degree of differences between the maritime sector in the different countries (largely due to historical reasons), status and level of RTD and international cooperation, different national priorities, available financial resources at national level and different funding schemes.

9.3 Conclusions

In terms of EU public R&D funding, the fact that some of the Member States could not participate due to lack of national funding means that EU efforts in the field are not enough. Furthermore, MARTEC does not seem to create additional mass for public funding. In terms of coordination and organisation, they are improving from MARTEC I to MARTEC II, enlarging the participation to important countries that were not there before (e.g. Italy). Finally, MARTEC ERA-NET is focused on industrial research and strongly regards competition issues. Participants are there mainly in order to secure a certain level of competences in a quite traditional area by strengthening international (EU) cooperation development.

10 The MATERA ERA-NET

10.1 Introduction

The main goal of MATERA, under the 6th EU Framework Programme, has been to create a durable cooperation platform for national and regional policy makers and managers having strategic activities in the field of materials science and engineering in Europe. With this platform the national and regional science and technology authorities aimed at improving the diffusion and transfer of knowledge and skills in Europe. MATERA has intensified the innovation value chain from basic materials science and engineering to the benefit of European society and business. It has also increased ambitious programme-type collaboration between European countries and regions in the field of materials science and engineering to deepen the European Research Area. The second long-term objective of MATERA was to strengthen new innovative material-related expertise and its utilisation in European business life and industry.

The main motivation for the creation of MATERA wasthe need to link the players active in R&D and the industry on the whole. In particular, it was aimed at a reduction of the time needed to pass from R&D results to their application in industry. This motivation of R&D-industry collaboration is also reflected by the fact that in MATERA both basic R&D organisations and R&D funding subjects are present. Players from many different technological fields are also present, representing the cross-sectoral specificity of MATERA.

FP6 MATERA ERA-NET started in 2005 and is about to come to a close (in May 2011). So far, five joint calls for industries, universities and research centres have been launched (2006, 2007, 2008, 2010 and 2011). As an outcome of the first three calls, a total of 25 trans-national projects have been funded with about 19 million euro. Additionally, in 2009 an ERA-NET Plus Call on materials (MATERA+) was launched with an option of an additional EC financial support call. The evaluation of the MATERA Call 2010 is ongoing, while the MATERA Call 2011 was opened at the beginning of November 2010 with a deadline of February 2011.

With regard to its geographical distribution, MATERA is widely distributed in Europe, covering ten EU countries (Belgium, Finland, Ireland, Italy, Latvia, Luxembourg, Poland, Slovenia, Spain and the UK) and five non-EU countries (Iceland, Israel, Norway, Switzerland and Turkey).

MATERA has a strong industrial characterisation, and the project beneficiaries in industry are key actors. This reflects the goal of linking R&D organisations to industrial companies and shortening the innovation chain (i.e. the chain between R&D results and their application in industry, usually around 10-15 years).

Research fields: materials science, nanoscience and nanotechnology.
Sector: industrial technology.
Overlaps with other ERA-Nets: some overlap with MNT-ERANET.
Duration: 6 years under FP6: February 2005 – May 2011.
EC funding: €2 343 300 (FP6, Source: CORDIS).

The ERA-NET consisted of 15 members from 13 countries at the beginning (in 2005, highlighted in bold). There are currently 18 members from 15 countries.

Coordinator: The National Technology Agency (Tekes), Finland

Partners:

1. **Finland: The Academy of Finland (AKA)**

2. **Belgium: The Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT)**
3. **Belgium: Ministry of the Walloon Region (DGTRE)**
4. **Iceland: The Icelandic Centre for Research (RANNIS)**
5. **Ireland: Enterprise Ireland (EI)**
6. Israel: Ministry of Science and Technology (MOST)
7. **Italy: Ministry for University, Education and Science (MIUR)**
8. **Latvia: The Latvian Council of Science (LCS)**
9. **Luxemburg: The National Research Fund (FNR)**
10. **Norway: The Research Council of Norway (RCN)**
11. Poland: National Centre for Research and Development (NCBiR)
12. **Slovenia: The Ministry of Higher Education, Science and Technology (MHEST)**
13. Spain: Madrid Region/Comunidad de Madrid (fmi+d)
14. Spain: Basque Government
15. **Switzerland: Innovation Promotion Agency (KTI/CTI)**
16. Turkey: The Scientific and Technological Research Council (TUBITAK)
17. **United Kingdom: Invest Northern Ireland (Invest NI)**

The only participant to leave the ERA-NET was the Ministry of Economic Affairs and Labour, North Rhine Westphalia (MWA-NRW, Germany). With regards to Poland, the NCBiR has substituted the Ministry of Scientific Research and Information Technology (MSRIT), the original Polish participant. New countries to enter have been Israel and Turkey.

This report is based on the following sources:

- Basic information from the CORDIS and MATERA websites.
- Responses of the coordinator and four participants to the CRIMASS online survey (*status of 31st January 2011*).
- In-depth interviews with the coordinator (TEKES, Finland) and the following participants: MIUR (Italy), LCS (Latvia).
- No Beneficiaries answers available.

10.2 Critical Mass analysis

10.2.1 External factors and policy objectives related to Critical Mass

We understand "Critical Mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field. This can be done first according to what the interviewees indicated as the ERA-NET's objectives.

Answer from the Coordinator:

- "to reach excellence".

Answers from the Participants:

- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (1)
- To reach excellence (2)

- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (1)

It is evident from these answers that the fifth objective ("excellence") is the most clearly agreed upon by the respondents. In particular, the coordinator addresses it as the only objective of MATERA. There is a lack of clarity to some degree in other participants' answers, although the third objective ("competences in a quite traditional area") might derive from the scientific characteristics of the field. Similarly, the sixth objective ("self-sustained dynamics") might reflect the aim of a participant to involve additional and new actors in the field through ERA-NET joint calls.

Given the industrial nature of MATERA, in which the type of research undertaken is mostly Applied and Development oriented, the first objective ("socio-technological challenge") and the second ("scientific challenge") are not relevant.

Policy objectives related to "Critical Mass" can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

Since the outset of the project, the coordinator of MATERA has been very active in the creation of the ERA-NET. Almost all other national programme managers and owners in the field (materials science) were asked to join the ERA-NET, and even before its formal start there were 8 partners actively involved. The number of participants in MATERA is considered adequate by the coordinator, but some countries are missing at the national level. In particular, Germany, France and the UK are missing in MATERA. At first, Germany was present at the regional level (with the Ministry of Innovation, Science, Research and Technology of North Rhine-Westfalia) but later left the ERA-NET. Other participants, very active at the beginning of MATERA, have since strongly reduced their involvement.

In terms of competitor countries in the field, the US and Japan have specific programmes in materials science. As a result, the MATERA coordinator – at least at the national level – has started a cooperation with these countries. This is considered a very important outcome of the ERA-NET: it has encouraged cooperation outside national borders. The pressure to have links with top countries like US and Japan has led to a bilateral programme for joint calls with Japan. This reflects the objective sequence that has been followed within MATERA: focus on the field (materials science); availability of funding beyond national borders; creation of cooperation and trust that goes beyond the ERA-NET. Of course, the involvement in this and the following of the sequence has varied from country to country.

From these descriptions, it appears that of the fifth Critical Mass objective is the most relevant for this ERA-NET, where the cooperation with top non-EU countries in the scientific field represents the best way to reach excellence. MATERA participants aim at, and are asked to target, the achievement of Critical Mass in order to be top players in materials science at the global level.

10.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give first indication on what kind of achievements can be expected.

MATERA has launched five joint calls for industries, universities and research centres. Thanks to the first three calls, 25 transnational projects are under way, while new ones are going to be funded after the current evaluation process. Some transnational projects have already been

terminated (e.g. FOULSURFACE – 3 project partners from Finland, Ireland and Norway – or DIWEAR – 3 project partners from Iceland, Luxembourg and Slovenia).

MATERA joint call projects meet the needs of smaller actors, especially SMEs, though all types of actors are eligible for funding in the projects. The average size of projects is around 3 partners, with a 700,000 uro budget and an average length of 36 months. Furthermore, MATERA projects need to have at least two beneficiaries from two different countries in order to be funded. Most of the selected beneficiaries are industries and SMEs, but academic beneficiaries are present as well.

MATERA projects are mainly close to the market and largely aimed at industry; they are expected to be innovative and, in some cases, bring radically new results. The international collaboration allows companies to leverage additional knowledge and experience that would have been much more difficult to obtain within the national context alone. The international collaboration is also intended to be a key determinant for the achievement of excellence by project partners.

From these responses, it becomes quite apparent that Critical Mass type 5 is in effect the most relevant for MATERA ERA-NET.

10.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives a first qualitative assessment on Critical Mass achievement.

The first step of the MATERA ERA-NET has been the coordination of a network of EU funding agencies in the field. This coordination has been very successful, even more than the integration of national programmes, where there still exists a high predominance of “national level” goals.

In general, the coordination and integration among different countries has required strong efforts, especially at the outset of the ERA-NET, because of the novelty of such scheme. It has since become easier to work at the international level.

Following the steps proposed by the EC, MATERA began by focusing on trust building among participants. Then the focus was moved to the launch of joint calls. Successively, non-R&D activities were set up, such as internal seminars, especially for the purpose of addressing future challenges. In addition, an expert database has been created, which can be used for maintaining a list of project evaluators within MATERA and for national programmes.

Given the partial overlapping of MATERA with another ERA-NET, that is MNT-ERA.NET, an additional effort in coordinating transnational activities outside of MATERA has been needed. In the case of these two ERA-NETs, in fact, it had sometimes happened that the forms for project applicants were very similar; and the applicants themselves were belonging to the same target groups. The result was that some applicants had no clear idea of the difference between the two ERA-NETs. Attempts to avoid duplications have then been made, leading to the launch of a joint call MATERA-MNT in 2008. Furthermore, there is the possibility of a future merger of MNT and MATERA.

Components of Critical Mass in funding programmes:

- Coverage of relevant countries: not enough, since at least three important countries are missing (France, Germany and the UK). Germany was present at the beginning with a regional representative that has since left.
- Number of participants: the constant increase of participants in the ERA-NET testifies the positive efforts of the coordinator in extending the geographical coverage. The personal commitment of the contact persons from each country must be emphasized. This personal

network has been considered one of the best achievements of MATERA coordination activities.

- Joint calls have been another strength of MATERA: 25 transnational projects already funded as a result of the first three (out of five) joint calls launched.
- The joint transnational call in 2008 has been launched in a coordinated way by MATERA and MNT-ERA.NET, indicating the high level of efforts in integrating EU R&D funding programmes in the field.
- The extension of the MATERA network to the ERA-NET PLUS scheme represents a positive result achieved in terms of strengthening EU integration. Even the possibility of merging MATERA and MNT can be seen as a step towards a larger and more coordinated network in this field of research.

➔ Author's comment: The joint calls' activity has been the most important activity of MATERA for the achievement of Critical Mass. This effort is clearly visible in the number of joint calls launched. In terms of integration, better results have been achieved through coordination of the network of contact persons and trust building. This has been possible even thanks to non-R&D activities such as mapping exercises, trials and seminars. The level of integration of EU national R&D programmes has been instead limited, due to the diversity of national rules for R&D programmes.

10.2.4 Critical Mass objective achievement

In this section the direct responses of the interviewees are reported, i.e. their own assessment to which of the objectives related to Critical Mass they are witnessing or expecting any progress.

Answer from coordinator: Progress been made with respect to five out of six objectives proposed in the survey. This represents a limitation in the results, given that the coordinator had clearly stated one objective only as the aim of the ERA-NET. Also participants see some progress for all the objectives, though with different indications, as reported below:

- To address socio-technological challenge (1 participant).
- To address scientific challenge (coordinator and 4 participants).
- To secure a certain level of competences in a quite traditional area, i.e. for defensive reasons (coordinator and 1 participant).
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (coordinator and 1 participant).
- To reach excellence (coordinator and 2 participants).
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (coordinator and 1 participant).

The self-assessment on the level of achievement gives a picture that is quite different from the one in the objectives. Some participants have very different views on what the ERA-NET should have achieved. Surprisingly, type 2 ("scientific challenge") has come out to be the result agreed upon by all respondents, while it was not declared as an objective by any of them. This stands as a limitation in the self-assessment of the participants. In other words, they all discover they have made steps forward in an area where results were not expected. The initial definitions and aims of MATERA ERA-NET were probably less clear than in other cases. Furthermore, the birth of the ERA-NET was under an industrial point of view, thus implying a lower expectation in scientific challenges.

On the other hand, the common agreement on the achievement of the second objective testifies that, within MATERA, the international cooperation of EU R&D programmes has led to a higher awareness on the scientific nature of the projects. As confirmed by the coordinator, the induced international cooperation has led to the high level of R&D activities undertaken within MATERA. Though the quality of the projects is considered on average similar to those undertaken under purely national programmes, there has been a fairly significant evidence of new links and networks among project applicants, thanks to the ERA-NET. This improved collaboration has made possible the progress towards addressing new scientific challenges.

Looking at the list of output indicators as reported by the interviewees and survey respondents, the author has drawn up a map of them, according to the different types of Critical Mass objectives. There are discrepancies in the responses collected, as can be seen in the table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New processes, products and services; Access to new markets.	The most important indicator (new process/products) is witnessed	*In the author's view this is obvious, given the industrial nature of the ERA-NET*
Address scientific challenge	Scientific publications, creation of access to new research fields	The most important indicators are witnessed / supposed, although not in a clear way	*In the author's view this reflects the scarce awareness of ERA-NET aims*
Securing a level of competence (defensive)	Scientific publications, improved processes etc., new research contracts.	The most important indicators are witnessed / supposed, although not in a clear way	
Securing a level of competence (prospective)	Scientific publications, improved processes etc., new research contracts.	The most important indicators are witnessed / supposed, although not in a clear way	
Reach Excellence	Scientific publications, improved position in international ranking, patents	The indicator of patents is the most clearly witnessed by all respondents	*In the author's view this confirms both the industrial nature of the ERA-NET and the scientific advancements*
Self-sustained dynamics	Scientific publications, additional researchers, networking, increasing number of actors	Almost all most important indicators witnessed, with a full agreement on the enhanced science-industry linkages	*In the author's view this confirms the positive coordination mechanisms put forward by the ERA-NET*

Overall, reaching excellence is one of the types of achievement supported by indicators' evidence, and it was the type indicated as an objective by the coordinator. In particular, the number of patent applications and patents granted (although never quantified by the respondents) indicates the effort of MATERA participants towards excellence in the research field. There is also evidence for addressing scientific challenges, mainly through scientific publications and access to new research fields. In this case there is a minor level of agreement among respondents.

In conclusion, the **achievement of no clear type of objective seems to come out from MATERA ERA-NET. There is evidence of partial achievements under different points of view; this can be linked to the lack of clarity in the aims set at the beginning of the ERA-NET. If "reaching excellence" was the aim for the coordinator – and this is partially confirmed with output indicators – the same does not apply for the respondent participants. Similarly, the progress made in "addressing scientific challenge" cannot be proof of a full achievement of Critical Mass from this perspective.**

10.2.5 Factors relevant for achievement or non-achievement

From the MATERA case study, we find the following set of explanations:

- **Coordinator's clearness in setting the objectives**:
  - The coordinator of MATERA has played a key role in networking and trust building.
  - Less clarity, or probably less effort, has been witnessed in setting the overall objectives of the ERA-NET.
- **Number of joint transnational activities**:
  - Given the applied research / industrial type of ERA-NET, the number of joint calls launched under the FP6 has become very important;
  - The level of integration outside the ERA-NET itself – thus referring to the joint call with MNT-ERA.NET, with which a merger is expected in the future – is also a signal of a positive factor for the achievement of the Critical Mass.
- **Scientific quality of the projects:**
  - International cooperation has led project applicants to perform better, if not in the quality of project itself, at least in the output. Among the results of MATERA projects, the following are clearly witnessed or expected: patents; scientific publications; new processes, products and services.

10.3 Conclusions

Through the analysis of the MATERA ERA-NET, it can be stated that the level of public R&D funding is not adequate. Specifically, unlike main global players in the field such as Japan or the US, not all EU countries have a national programme in the materials science field. Nevertheless, the integration of existing EU R&D programmes in the field is still difficult, due to the predominance of the national level approach as opposed to the EU-wide one. This integration objective has not been fully achieved as of yet.

Coordination activities within MATERA required some effort but, after the difficulties at the outset, trust among the national contact persons clearly emerged. This has led to a strong personal commitment, that is believed to be a crucial point for the achievement of Critical Mass, at least from the organization and coordination point of view.

Overlaps with another ERA-NET, the MNT-ERA.NET, can represent a certain degree of unclearness in EU R&D programmes. As the integration of EU R&D programmes is still a "work in progress", the integration efforts undertaken in MATERA should be appreciated. In particular, the joint transnational call MATERA launched together with MNT in 2008, as well as the possibility of a future merger of these two ERA-NETs, testifies the progress made in this direction.

Furthermore, this merger would increase the size and the scope of EU R&D joint programmes. Although MATERA has a more cross-sectoral characterization while MNT has a more focused one, both the fields of innovative materials and micro/nano-technologies would reap an advantage from such an ERA-NET merger. In particular, it would allow for more widespread geographical coverage, given that some large countries missing in MNT (e.g. Italy) are present in MATERA and some large countries missing in MATERA (e.g. France and Germany) are present in MNT. Finally, this would help in overcoming competition among EU R&D programmes and in improving cross-sectoral integration.

11 The MNT-ERA.NET

11.1 Introduction

MNT-ERA.NET is a large project associated with the European Micro and NanoTechnology (MNT) support programmes. MNT-ERA.NET's activities aim at enhancing the competitiveness of European industry by coordinating and streamlining European support measures for micro and nanotechnologies. This is achieved by implementing coordinated activities and securing sustainable cooperation between the participating funding programmes. MNT-ERA.NET is offering annual Transnational Calls for collaborative projects, reflecting the needs and challenges identified by the European R&D community. As an attractive instrument for supporting transnational R&D, it is complementing the portfolio of European funding initiatives. MNT-ERA.NET improves the cooperation between funding organisations, industry partners, research institutions and universities and provides practical aspects of innovation through close relations to national and regional clients. This ERA-NET is expected to have a big impact on Europe's contribution to new technology. The sharing of best practices should lead to better designed research programmes, and the strong transnational partnerships should yield results of lasting value to both science and industry.

MNT-ERA.NET was founded by VDI/VDE (Germany) and FFG Austrian Research Promotion Agency (previously FFF), starting from a "micro system" initiative, inside their R&D programmes, which they had in common. The choice of the "*micro and nano systems*" sector was the result of this previous connection but also in response to the strategic importance of the sector in the new century. The submission of the proposal for the creation of the ERA-NET was presented in 2003 by those two organisations together with organisations from other six programme/countries (Ireland, Switzerland, Norway, Sweden, the Netherlands, the Basque country). The ERA-NET started in January 2004 with FFF as a coordinator. In September 2004 FFF became FFG and continued to coordinate MNT.

Research fields: industrial production; nanotechnology and nanosciences; micro-systems; micro technology.
Sector: industrial technologies.
Overlaps with other ERA-Nets: some overlap with MATERA and MANUNET ERA-NETs.
Duration: 5 years under FP6: January 2004 – December 2008; second phase under FP7: March 2009 – August 2011.
EC funding: €3 100 000 (FP6, Source: CORDIS).

The ERANET consisted of 22 members from 17 countries at the end of FP6 period. Only eight members were present at the beginning (in 2004, highlighted in bold).
Coordinator: Austrian Research Promotion Agency, Division General Programmes (FFG BP), Austria.
Partners:

66. Belgium/Flanders: Instituut voor de Aanmoediging van Innovatie door Wetenschap en Technologie in Vlaanderen (IWT)
67. Belgium/Wallonia: Directorate General for Technologies, Research and Energy (DGTRE)
68. Czech Republic: Czech Society for New Materials and Technologies (CSNMT)
69. Finland: National Technology Agency (TEKES)

70. France: Conseil Régional Midi- Pyrenées
71. France: CEA Leti
72. France: OSEO
73. **Germany: VDI/VDE Innovation + Technik GmbH**
74. Germany: Forschungszentrum Karlsruhe (PT Karlsruhe)
75. **Ireland: Enterprise Ireland**
76. **The Netherlands: SenterNovem**
77. **Norway: The Research Council of Norway**
78. Poland: Ministry of Scientific Research and Information Technology (MSRIT)
79. Romania: Politehnica University of Bucharest (PUB)
80. Slovakia: Slovak Academy of Sciences (SAS)
81. Slovenia: Ministry of Education, Science and Sport (MESS)
82. **Spain: Industry, Trade and Tourism Department of the Basque Government**
83. Spain: Ministry for Education and Science (MEC)
84. **Sweden: Swedish Agency for Innovation Systems (Vinnova)**
85. **Switzerland: TEMAS AG Technology Management**
86. United Kingdom: Invest Northern Ireland (Invest NI)

MNT-ERA.NET is continuing its activities under the 7th EU Framework Programme until 2011. In 2011 participation was extended to include additional countries including Turkey and Cyprus. MNT-ERA.NET now comprises 21 European countries and regions, all represented by national and regional ministries or funding agencies. Some major countries are not involved (such as the UK and Italy).

This report is based on the following sources:

- Basic information from CORDIS and MNT-ERA.NET website.
- Responses of the coordinator and five participants to the CRIMASS online survey (*as of 31st January 2011*).
- In-depth interviews with the coordinator (FFG, Austria) and the following participants: CSNMT (Czech Republic), KIT-PTKA (Germany).
- No Beneficiaries' answers available.

11.2 Critical Mass analysis

11.2.1 External factors and policy objectives related to Critical Mass

We understand "Critical Mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field. This can be done first according to what the interviewees indicated as the ERA-NET's objectives.

Answers from Coordinator:

- "to address socio-technological challenge";
- "to secure a certain level of competences in a quite traditional area, i.e. for defensive reasons";
- "to reach excellence";
- "to reach self-sustained dynamics in the development of the area".

Answers from Participants:

- To address socio-technological challenge (3)
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (2)
- To reach excellence (2)
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (4)

It is evident from these answers that the objectives of the ERA-Net are quite unclear for participants, though they generally selected the same answers as the coordinator. Type 6 ("self-sustained dynamics") is the most often mentioned (five times including the coordinator). However, type 1 ("socio-technological challenge") also appears to be clearly individuated as a crucial objective. Reasons for this variation might be the different national interests in this field or the different profiles of the respondents (innovation agencies, R&D management companies, governmental bodies). What is clearly emerging from the answers is that type 2 ("scientific challenge") and type 3 ("secure competencies for defensive reasons") are not relevant. This might derive on the one side from the industrial nature of the ERA-NET – where the purely scientific approach counts less – and on the other side from the innovation of the research field – a sector that is not traditional at all.

Policy objectives related to "Critical Mass" can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

Participation in the MNT-ERA.NET has allowed the participants to achieve the stated objectives better than by simply participating in national programmes. This is because MNT-ERA.NET has created a close network in which each actor is strongly committed to give a full effort, increasing each ones' competencies in this new sector and allowing for the funding of common topics agreed upon at the transnational level because of a commitment to pursue a common scientific challenge. As a result, interesting and truly innovative projects have been funded.

In terms of competitor countries, the US, China, Japan and Korea are investing large sums of public money into research programmes in this field. In any case, Europe has a strong research base in many MNT areas such as health care, information technologies, materials science, manufacturing, instrumentation, energy, security and space, but its funding programmes are fragmented and dispersed among many national funding agencies. As a large European funding network, MNT-ERA.NET was from the very beginning intended to stimulate close cooperation of national and regional R&D programmes. These efforts were aimed at significantly contributing to strengthening the position of the European economy in this crucial market.

In general, all participants consider MNT-ERA.NET an opportunity for their national industry to be engaged in international collaboration. The partners were (for the most part) already well connected before the emergence of the ERA-NET scheme, but more on a bilateral level. Thus, the ERA-NET has provided the ability to exchange views and experiences and to co-programme activities in a multilateral and more systematic and comprehensive manner. Further, the system provides an incentive for participants and applicants since, through ERA-NET plus, extra money is mobilized for MNT research fields without the high formal requirements of FP project applications, which eases the administrative burden of individual transnational framework projects.

From these descriptions it appears that type 6 of the Critical Mass objectives is the most relevant for this ERA-NET, where the higher involvement of leading actors and the integration of R&D programmes might represent the key for the competitiveness of the EU on a global scale.

11.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give first indication on what kind of achievements can be expected.

MNT-ERA.NET was originally offering annual joint calls for collaborative projects, reflecting the needs and challenges identified by the European R&D community. In fact, since 2006, there have been five MNT joint calls; 98 transnational projects have already been funded, of which some shorter projects are already concluded.

MNT-ERA.NET joint call projects meet the needs of smaller actors better, as they are quite flexible: not all participating countries need to join each call, so there is no obligation to proceed together in all approaches. Furthermore, MNT-ERA.NET projects need to have at least two beneficiaries from two different countries. The average number of beneficiaries in projects is 2.5, and a fact which is highly appreciated by applicant companies because it tends to reduce complexity in project bureaucracy and coordination. Most of the selected beneficiaries are industries and SMEs; some academic beneficiaries are present, but only in partnerships with companies. This depends also on countries' programme rules. More than 50% are companies, with a ratio of 2/3 out of 3/4 of SMEs versus big companies.

MNT-funded projects are all close to market and largely industry aimed, although the consortia include partners from academia, research organisations and industry alike. The projects are close to the market, innovative, but generally selected to have medium to low technical and commercial risk. This implies that the chances of the projects of reaching their objectives is fairly high. International collaboration allows companies to leverage additional knowledge and experience that would have been much more difficult to obtain within the national context alone.

From such answers it appears quite clearly that the Critical Mass type 6 objective is in effect the most relevant for the MNT-ERA.NET.

11.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives a first qualitative assessment on Critical Mass achievement.

Inside the MNT-ERA.NET, an initiative has been started for monitoring the results of the first funded projects (2006 and 2007 calls), asking beneficiaries if they are increasing expenses and turnover on R&D, if they are increasing budget, patents, cooperation, if they are going to continue collaborating with their partners, and about their products and their launch/presence in the market.

One critical factor in pooling resources within MNT-ERA.NET is the existence of two "budget approaches" at the country level, in order to plan resources dedicated to this ERA-NET initiative. The first approach is a commitment of a country from the very beginning in terms of total amount of funds for ERA-NET projects; while the second approach is to have a flexible budget and to fund as many good projects as are presented each year, in terms of national programmes as well as ERA-NET calls. In one example cited in an interview, a country can literally approve only two or three projects if these are the only ones of good quality submitted in a year.

These different approaches are leading to unbalanced situations in the case of large countries. For example, if a large country does not invest a large amount of money in a call, this implies a small number of approved projects with participants from that country. This leads to decreased interest

in the joint calls by participants from other countries because a lot of companies are interested in participating only if they can do so in partnership with companies from the large country. The result is that not all countries apply to a call, knowing that the most relevant partners may not participate. On the other side, for large countries' participants, not all countries are of interest, so they tend to participate in a moderate way.

Inside the MNT-ERA.NET, participants have discussed the necessity of establishing a common pot approach in joint calls. Due to the precompetitive research they fund, however, it is not possible and not recommended to give money out to industries not at the national level.

Components of Critical Mass in funding programmes:

- Coverage of relevant countries: fairly good, though at least two important countries are missing (Italy and the UK).
- Number of participants: the constant increase of participants in the ERA-NET testifies to the positive efforts of the coordinator in extending the geographical coverage.
- Joint calls have been the real strength of the MNT-ERA.NET, with almost one hundred projects already funded and several success stories (as highlighted also on the website).
- After the pilot call in 2006, the Transnational Call 2007 included 19 participating programmes. The Transnational Call 2008 was also coordinated with MATERA, indicating the high level of efforts in integrating EU R&D funding programmes in the field.
- The extension of this funding programmes network, as well as the continuation of MNT under FP7 show the positive results achieved in terms of strengthening EU integration. Even the possibility of merging MNT and MATERA can be seen as a step towards a larger and more coordinated network in this field of research.

➔ Author's comment: Joint calls' activity has been intended to serve as the most important indicator for the achievement of Critical Mass within this ERA-NET. This effort is clearly visible in the number of joint calls launched, in the increasing integration of national programmes and in the number of funded projects.

11.2.4 Crtical Mass objective achievement

In this section the direct responses of the interviewees are reported, i.e. their own assessment to which of the objectives related to Critical Mass they are witnessing or expecting any progress.

Answer from coordinator: with respect to all four objectives mentioned above, steps have been made forward. Also participants see some progress for some objectives, though indications here are partly different from their initial answers:

- To address socio-technological challenge (coordinator and 2 participants).
- To address scientific challenge (2 participants).
- To secure a certain level of competences in a very new area, i.e. for prospective reasons (coordinator and 3 participants).
- To reach excellence (coordinator and 3 participants).
- To reach self-sustained dynamics in the development of the area (involvement of key actors, investment of research funds, etc.) (coordinator and 3 participants).

The self-assessment on the level of achievement gives a similar picture as that presented by the objectives. Some participants have very different views on what the ERA-NET should have achieved. This might be connected to the fact that the high efforts in launching joint calls have

probably implied less discussion on the agreement of MNT-ERA.NET objectives. In other words, transnational activities have been many and effective, though each participant has seen them from a different perspective.

Looking at the list of output indicators as reported by the interviewees and survey respondents the author has created a map of them, according to the different types of Critical Mass objectives. There are discrepancies in the responses, as can be seen in the table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New processes, products and services; Access to new markets.	The most important indicators are witnessed / supposed by almost all the respondents.	
Address scientific challenge	Scientific publications, creation of access to new research fields	The most important indicators are witnessed / supposed, although less than for type 1	*In the author's view less applicable than type 1*
Securing a level of competence (defensive)	*Not applicable*		
Securing a level of competence (prospective)	Scientific publications, improved processes etc., new research contracts.	Almost all most important indicators witnessed, although only new research contracts by all respondents	
Reach Excellence	Scientific publications, improved position in international ranking, market share of the EU / world business sector.	The indicators for this type are the weakest	*No real agreement by respondents.*
Self-sustained dynamics	Scientific publications, additional researchers, networking, increasing number of actors active in the field	Almost all most important indicators witnessed, with a full agreement on networking	*In the author's view this is the clearest applicable type of Critical Mass achievement*

Overall, reaching self-sustained dynamics is the type of achievement more clearly supported by the indicators, at least if compared to other types. There is also evidence for securing a level of competence, but with a minor level of agreement among respondents. In conclusion, the **achievement of such an objective seems to be partial, probably because it was not explicitly declared from the beginning. However, there are factors (in terms of outputs) suggesting that the ERA-NET is moving in the right direction with regard to such achievement.**

11.2.5 Factors relevant for achievement or non-achievement

We can determine from what has been said so far and from more statements of the interviewees the factors relevant for the described achievements and the reasons for non-achievement. From the MNT-ERA.NET case study, we find the following set of explanations:

- **Coordinator's engagement**:
  - The coordinator of MNT-ERA.NET has played a key role in trying to extend the network and integrate the different national programmes.

- The experience of the coordinator has helped in increasing the integration of participants within the ERA-NET.

- **Number of joint transnational activities**:
  - Given the applied research / industrial type of ERA-NET, the number of joint calls launched under the FP6 is significant;
  - The level of integration outside the ERA-NET itself – thus referring to the joint call with MATERA ERA-NET, with which a merger is expected in the future – is also a positive signal for the achievement of the Critical Mass.

11.3 Conclusions

Through the analysis of MNT-ERA.NET, it has become clear that the level of public R&D funding in the micro- and nano-technologies sector in the EU is quite high, especially in some EU countries. For example, in the coordinator's country (Austria), the programme budget is the highest within the coordinator's activities. The idea of MNT-ERA.NET was precisely to enlarge this kind of initiative to as many actors as possible. This objective has been achieved, though some large countries (e.g. Italy and the UK) still do not have a national programme for financing research in this sector.

Coordination activities within MNT-ERA.NET requested big efforts, especially in terms of involvement of key actors in the field. Steps forward have been made in the organisation and integration among EU national programmes thanks to this ERA-NET. After the activities of both FP6 and FP7 MNT, the aim is to create an EU Joint Programme for micro- and nano-technologies, as an achievement of the coordination efforts of the past years.

Overlap with other ERA-NETs testifies to a certain degree of overlap among some EU public programmes, especially with the overall manufacturing R&D programmes (represented by the MANUNET ERA-NET) and the materials science programmes (represented by MATERA). In fact, a joint transnational call was launched with MATERA in 2008, and there is the possibility of a future merger of MNT and MATERA. This merger would increase the size and the scope of the R&D joint programme in the field of innovative materials and micro/nano-technologies. Covering the same topics with a single ERA-NET would allow for more widespread geographic coverage (with a larger dimension) and would allow for the saving of time spent on coordination and administrative activities (e.g. reducing the number of meetings per year). Additionally, this would avoid the presence of competition among different EU R&D programmes and increase cross-sectoral integration.

12 The ERA-NET NET-BIOME

12.1 Introduction

Net-Biome (NB hereafter) is a regional ERA-NET (EN hereafter) project in the field of biodiversity, global change and sustainable development under the EU 6th Framework Programme (sub-priority 6.3 "Global Change and Ecosystems"). NB is a consortium of 11 partners: 7 outermost Regions (Madeira, Canary Islands, Azores, Martinique, Guadeloupe, Guyana, La Réunion) and several overseas territories. These Regions and Territories are characterised by 3 main features: (a) an exceptional terrestrial and marine biodiversity (b) climate change impact, natural hazards and pressures of human activities affect their environments (c) biodiversity is a fundamental asset for their economic development.

For several reasons (distances, isolation, deficiency of resources and critical mass, access to facilities and information), research activities are poorly coordinated and cooperation between the actors, between the regions themselves and between them and continental EU is week. Therefore, there is a lack of trans-regional funding and integration of research on biodiversity. This regional EN aims at initiating and stimulating cooperation and coordination of research programmes for the sustainable and integrated management of biodiversity

The project is coordinated by the Regional Council of La Réunion, it has started in March 2007 and will last 48 months.

Research Fields: marine and terrestrial biodiversity, conservation, evolution and sustainability of biodiversity
Sector: environment
Overlaps with other ERA-Nets: complementarities with Biodiversa
Type of research: Basic and applied research
Duration: 48 months (start: March 2007 – end: February 2011)
EC funding: project cost = project funding = 2.52 million euro (Source = Cordis)

11 partners : 7 outermost regions + overseas territories
Coordinator: La Réunion region
Partners:

- Martinique Region, France
- Guadeloupe Region, France
- Guiana Region, France
- French Polynesia, France
- New Caledonia, France
- Azores Region, Portugal
- Madeira Region, Portugal
- Canary Islands, Spain
- NL overseas territories: Curaçao, St Marteen, Bonaire, Saba and St Eustatius
- UK overseas territories: Cayman Islands, Turks and Caicos Islands, British Virgin Islands, Anguilla, Montserrat, Ascension Island, St Helena, British Indian Ocean Territory and the Pitcairn Islands groups

This report is based on the following sources:

- Basic information from CORDIS
- Responses of coordinator and participants to CRIMASS online survey (*status of 31 January 2011*).
- In-depth interviews with the coordinator and three partners
- No Beneficiaries identified.

12.2 Critical Mass analysis

12.2.1 External factors and policy objectives related to Critical Mass

1. Environmental characteristics

a. General context:

The origin of the project is based on the fact that the rate of participation and the rate of success to FP programmes of the research organisations located in ORs were generally very weak. The presidents of the Conference of ORs wanted a better participation of their research forces in FPs; even if some adaptations would be needed. NB was a way for these regions to coordinate their action, to change their discourse and to become a force of proposition in the research area of tropical and subtropical biodiversity. The Presidents of the Conference of ORs decided to launch an EN under FP6 (among the last FP6 EN). This EN was a good way to open up the door to FP programmes and to change the vision they could have vis-à-vis EU and vice and versa.

Other contextual reasons to set up NB could be summarized as follows:

1. There is an exceptional biodiversity in the partnering regions, at all respect from animal to vegetal, and with implications and links to many activities such as agriculture, tourism, fisheries, green chemistry, medicine, etc. In addition, some research labs are working in the field in those regions. But in terms of research agenda and funds allocations, most of the decision are taken by the continent, and are not always fully in accordance with needs and capacities of those regions; NB is a means to have more power in this policy area
2. OT are linked to the European governments but are not strictly part of the European Union and do not share all its benefits. Most are small, fragile islands or archipelagos with a wide range of marine and terrestrial habitats and a high proportion of endemic species. Their biodiversity is important and supports their small economies highly sensitive to external pressures. These Territories lag behind Member States in terms of environmental protection and endure poorly regulated tourism, unsustainable development, inappropriate land management and the impact of invasive species. Many are also vulnerable to climate change and may indeed provide early indications of its effects.
3. At EC level, taking into consideration those regions is emerging, but the question is raised about the necessity to develop very specific tools; then NB was also to show that, despite their specificities, those regions were able to use the "standard" EC tools and were not necessarily to be treated differently from the other EC regions
4. correspondingly, NB was set up as a way for the institutional participants but also for the labs to develop capacities for being more involved in EC programmes in the future ("to give them a leg up")
5. Biodiversity was chosen rather than other candidate topics such as renewable energy or risk, because it includes the largest research and "user" community with the more diversified scope of fields: urban and rural planning, agriculture, tourism, cultural activities,

green chemistry, medicinal plants, etc. All dimensions of biodiversity are potentially here to be taken into consideration, as well as all dimensions of consequence of actions or phenomenon that affects biodiversity (ex : bank up or not mangroves for building a new touristic resort : what impact on biodiversity ? what economic impact ? etc)

In the set up of NB, the leading bodies were French, and especially La Réunion. Previously, there was some cooperation at institutional level between the OR (through the Conference of OR), with thematic groups. NB was also a way to reinforce some Interreg III Strand B (transnational in large geographical area) initiatives that were too sporadic. At research level, cooperation was not so developed, apart from local cooperation between neighboring regions. Cooperation was essentially relying on individuals. For cooperation between distant regions, the main obstacle is obviously the travel cost.

b. Scientific context

Tropical and subtropical biodiversity is partly explored but with a lot of research going on and an increasing number of research teams involved. It is dominated by a few key actors located in Brazil, India, France, Portugal and Spain. This area of research is heavily connected to ongoing research activities in other fields. It is connected to future and foreseeable market.

In NB, there is a large heterogeneity between the different participating regions in terms of size (population for instance) and research capacity (La Réunion is the largest one). In the French islands there are several reputed research institutions working on biodiversity: CIRAD, IFREMER, INRA and universities. They cooperate with neighbouring regions such as Madagascar for la Réunion or Brazil for Guiana

There is also some forms of specialization in research, although mapping of this diversity is precisely one of the aim of NB ; for instance in University of Antilles-Guiana, natural science are mostly in Guadeloupe, Social sciences are in Martinique, specific study of forest and Amazonian environment are in Guiana; etc. In UK and NL participants, there are mostly research teams coming from Europe, making field works and then coming back. In the UK there are no research institutes in OT. There are no large universities but only high schools and thus the research capacity in the territories is limited. Some large UK universities are involved in research on biodiversity: Plymouth University, Birmingham University, Edinburgh University; Cambridge University. They do their research in the UK and field work in OT. This raises the issue of the existence of long lasting benefits for these regions

Given the diversity of the research fields covered by NB, there is no clear conclusion about the role of large Research Infrastructure. However, there are some, for instance marine platform in Portugal, Center for Tropical Biological Resources (= a labeled bio-bank) in continental France-Montpellier, Observatory (French Polynesia), a “pôle” of plant protection and a cyclotron dealing with bio-molecules (La Réunion). It is important to value these infrastructures at the regional level.

It is important to bear in mind that in NB, biodiversity is studied in a perspective of sustainable development, including space planning. This implies that activities such as inventory, identification, are also included in the perimeter covered by NB. In that area, countries like UK and NL exhibit some differences: these activities involve many Not-For-Profit organizations.

2. Policy objectives recapitulation

The overall objective of NET-BIOME is to network the Regional Research Policies on sustainable management of biodiversity in the European tropical and subtropical outermost Regions and Territories, in order to:

- Develop a durable partnership in research funding and practice between Regions, thereby placing the responsibility on the ORs and OCTs of the research strategy and bringing research on biodiversity closer to the Regions,
- Creating added value in high quality tropical and sub tropical research across the seas
- Develop a trans-regional research funding programme between the Regions
- Build a better interface between regional, national, EU and international structures
- Facilitate reciprocal opening of regional programmes, develop joint calls and trans-regional“ sustainable management of biodiversity” programmes
- Support the outermost regions in the designing of their common research policy strategy allowing to build the beginning of an EU tropical and subtropical component of the EU Research strategy
- Contribute to the coordination of biodiversity research funding policies of the outermost regions and territories in cooperation with developing countries;
- support long-term perspectives in European research policies to address the need to prevent, avoid and remediate the serious impacts of climate change and human pressures on tropical and subtropical biodiversity

Apart from these policy objectives, the aim of the participants was to:

- create and support trans-regional projects in a field which requires trans-regional cooperation
- learn from funders and sharing information between funders in other countries
- network and build new relationships with funders from other countries
- improve own R&D programmes
- opening up of national programmes in existing or new areas of research
- increase the visibility, research management capacity building, research governance building, bottom-up approach towards national and European scales.

3. Consequence in terms of critical mass objective

For the ERA-Net activities in general, the interviewed persons identified the following objectives:

- “to address socio-technological or scientific challenge" (1 respondent): in NB one of the aims is to develop scientific knowledge at the service of biodiversity. There is a need to develop new competencies for the preservation and the valuation of the biodiversity. For instance the destruction of the housing environment by cyclones or landslide is a major threat in the islands. The presence of invasive species is another important threat. Research is needed in these areas. The "scientific challenge" aspect of this critical mass is related to the interdisciplinarity, complementarity and the global approach. Challenges are also in terms of tackling research issues in a global way instead of considering only local problems.
- “to secure a certain level of competences” (2 respondents) : there is a need to maintain or reinforce competences in areas such as plant protection and emerging disease. There is also a need to avoid general disaffection for natural science, and for some specific areas covered by the call

- "to reach excellence" (2 respondents) : the aim of NB is to become visible internationally in the tropical and sub tropical biodiversity. Canada is very advanced in this topic.
- "to reach self-sustained dynamics in the development of the area"(2 respondents) : is vital for NB. The idea of the project is to develop research that ensures sustainable development. Thus what is important is to find the way of networking that ensures appropriate exchange of information about biodiversity issues. It is also crucial that the research done in NB has impact on the selected Regions. They aim at developing locally adapted solution to answer local, regional and more global problems. At the EU level, there is a political aim to take account of neighbouring regions. By the geographic position of NB, it is a good candidate to open its network to other regional systems. NB could be at the origin of a snowball effect for these neighbouring regions. They aim at being able to pool all ORs and OCTs to create common research activities. EU instruments for such actions do not exist for the moment. One of the key aspects is to implement renewed local governance: to involve all the actors interested by and the users of biodiversity (including private actors). It will be difficult for Regions to fund alone ambitious research programmes. They should develop a dynamic of partnerships involving EU, national government and private actors.

Most obviously from the above analysis of the context and the policy objectives appear the following types of objectives:

- "to address socio-technological or scientific challenge":
- "to reach self-sustained dynamics in the development of the area"

12.2.2 Determinants of Critical Mass

1. Activities….

a. … In general….

The different activities developed by the consortium are the following:

- State of the art of the research activities developed in each region: they surveyed the main research actors and asked questions about their projects, research themes, funding sources and amount etc. They created a data base
- Survey of the NB partners about the management of the research in each region: type of support, evolution of the research, research priority, quality management of the research. There are few funding schemes based on call for proposals at the regional level. They worked on the concept of programme: they want to better define and evaluated research. They also discussed the implication of funding research with calls: evaluation criteria, external expertise, defining a committee of experts etc.
- They synthesised the two first activities to define their research priorities: 3 priorities (see call). The funded research should be cooperative and interdisciplinary. One of their ideas is that it is important to create and interface between the political and the scientific worlds. The local government could play this role and NB is seen as a place of dialogue between these actors (politicians and scientists).
- Defining procedures and evaluation mechanisms for the call
- Favouring clustering of existing projects: to be done
- Develop strategies for the mutual access of infrastructures and large equipments: to be done
- Work on the researchers mobility: to be done

- Opening up the network to other European partners and internationally: to be done

For some partners, some activities are particularly important:

- **Mapping of research activities** and resources and setting up a corresponding data base;
- **Setting up a strategy** for organizing tools, financial, human and technical resources; the general aim is to organize and structure research as well as policy/institutional activities in a long term perspective. The general scheme is already elaborated and has been presented to the elected bodies of the participating regions
- **Opening to external partners**. Contacts have been established with 2 existing INCO-Net (one in the Caribbean area). Note that there are some contacts with the continental EN as well.
- **mobility** : now there are using existing schemes such as Campus France, but nothing specific has been added
- **mutual access to research infrastructure**: not yet developed, depends largely on the mapping of resources presently performed

NB has asked for an extension to complete the some activities. The extension should also allow them working on the continuity of NB. There is a clear willingness to find a way to keep on supporting visibility of research related actors, to as a spokesman for them, to conduct calls, etc. One possibility is to set up an association, but it is "too classical". Another solution is to set up an European grouping of territorial cooperation (EGTC), i.e. a special entity set up in order to implement territorial cooperation projects co-financed by the Community or undertake territorial cooperation measures at the initiative of the Member States. But it is seen as far much too complex and OCTs cannot be in. EN+ is not seen as an option. So the participants still have to discuss the future solution.

b. …. The call

They have launched a call that has opened on November 26th 2010 and will close on February 28th 2011. They have selected **three topics**:

- The use, evaluation and valuation of biodiversity and the services and resources it provides, underpinning the sustainable use of natural resources (e.g. agriculture and fisheries) and including those with important cultural and aesthetic resonances. It is oriented towards application, social utility, and economic development. For instance, in terms of biodiversity protection and related impact, questions such as the social utility of building a new hotel, the difference of an investment in one island as compared to similar investment in other Caribbean island etc.
- Improving Spatial Planning and Coastal Zone Management in order to support the sustainable management and use of biodiversity (marine and terrestrial) in the context of human pressures and global change. This one is more fundamental research oriented, with global aim of contributing to a better preservation, especially in a context of climate change and bio change
- Characterizing biodiversity (from gene to ecosystem level and through to landscape) and the drivers of its evolution in a way that will enhance local capacity and improve policy decision-making. In terms of orientation, this third topic is between the two preceding ones. It deals with resources management for sustainable development and conflicts for usage especially in "buffer zones" (example fisheries resources, such as eels).

Pluridisciplinarity is encouraged in all topics. Topics have been chosen on the basis of the first round of data base/mapping, call for interest on the side of decision-makers, and the use of a scientific advisory board. At that stage topics are not directly stemming from the strategy which is still in elaboration, since strategy is not so much about defining the research agenda than about designing the tools and means for organizing and mobilizing resources, to "set in capacity".

The call is a **common virtual pot type**. The total funding amounts to € 3.490.000, out of which:

- France (ANR-National Research Agency) : 1.5 million €
- Reunion, Guadeloupe (GUA-REG), French Guiana, Martinique, ADECAL- New Caledonia: 1.340.000€
- Spain (Canary Islands): € 200.000
- Portugal (FCT), Azores and Madeira: € 450.000

On the French side, the ANR is participating to the call. It has a budget on biodiversity. ANR has followed the NB project since the beginning and is a member of the expert committee of NB.
On the Portuguese side, the FCT (national funding agency) has no specific programme on biodiversity but have calls on maritime sciences for instance.

Some French Regional Councils would be ready to fund beneficiaries from other (including non French) regions if the beneficiaries' regions (ORs or OCTs) do not bring enough funding. They have to analyse the legal and technical aspects related to the possibility to fund partners that are not located in the Region aiming at supporting them. In the future they would like to use a “mix pot” solution: each Region will devote x% for their regional beneficiaries and (1-x)% for third parties. This solution will mainly be adopted for economic reasons: Regions have not so much money but biodiversity is a crucial topic for them. But, **to open the call financially to other potential partners** of the concerned geographical zones, they should develop further legal aspects.

Even though UK, NL and French Polynesia could not provide funding, the members wanted them to be involved in the call. They are member of the steering committee. All these partners have asked the potential beneficiaries to answer to the Manifestation of Interest (MOI).

For the call they aim at working with **international evaluators** who have a global vision of biodiversity but also a competence on subtropical diversity at the regional level. The call is open to all countries but only the partners with funding are eligible for receiving funds

2. Organisation of the activities

a. In general

There is an executive committee in which all operational people of the partners are present. Its target is to implement NB and the WP
At the level of the Regions, the decisions should be validated by the political area.
There is a governing board in which all the vice presidents and/or directors in charge of the regional research affairs are members. The governing board gives the strategic orientation of NB.
There is an advisory board with operational persons + national funding agencies + NGOs

NB has witnesses **some delays** for the following reasons:

- They needed time to appropriate the project

- They took time to launch the different surveys and working groups
- Difficult to understand what was an EN
- All the operational persons in the different regions were not attached to the research division of their region
- High turnover of operational persons in some regions
- Coordination issues
- Different tasks have been assigned to different partners but not always in a coherent way. They have reorganised some WP, the tasks allocated to the participants and the way to coordinate them.

A core of partners is very active.

Some other **shortages** were underlined:

- The EU rules to handle with money between the partners are too restrictive.
- Problems of linkage between the executive and political part of the project: sometimes too rigid and executive board too dependent on governing boards decision – lack of flexibility.

b. Overlap with other ERA-Nets:

Biodiversa is an EN on biodiversity in general involving national funding agencies and Ministries. NB started almost at the same time as Biodiversa ended. These two EN are complementary.
They could have collaborated more with Biodiversa2 in order to avoid some duplication of efforts. The collaboration between EN should be promoted. For instance, they could have certainly used the database of Biodiversa to gain time on some issues.

c. Comparison of ERA-Net activities to national /regional programmes:

There is **no programme similar to NB** in terms of institutional arrangement. In the field of biodiversity, there are some projects, but absolutely not comparable in terms of size and geographical scope. Smaller and "local" ones exist through Interreg, or cooperation with neighboring countries.
Sometimes Regional Directorates for Research manage research programmes with simple rules for funding but without cooperation requirement between the actors: budget and funded teams are smaller.
NB is more complex than other programmes, because it is bigger, with other different regions etc. The same for the researchers, because partnership is more complex, moreover there is no such "partnership events" usually organized in Europe (because of geographic conditions).
But NB is less complex than Interreg when OR and OCT have to work together because the funding mechanisms (Feder for ORs and Fed for OCTs) are hardly compatible in practice. NB is between National programmes and the simplest EC FP programmes in terms of complexity.
NB is different from what the Regions were used to do: they have to manage what was previously sub-contracted to other institutions and in particular funding agencies. This means some reorganization.

3. Participants

There are **four types of participants** in NB:

- **Regions**: La Réunion, Guadeloupe, Martinique, French Guiana, Azores, Canary Islands and Madeira. The Regions are more or less autonomous towards the National government. They have their own competences and share some other with the national government.

- **OT**: French Polynesia and New Caledonia
- **NGO**: UKOTCF brings together non-governmental organisations and institutions involved with furthering conservation of the natural heritage in the Overseas Territories in the UK.
- **Ministry**: Ministry of Public Health and Social Development, Netherlands Antilles Government - VSO-MINA

12.2.3 Components of Critical Mass

As the call is not yet closed there is no available information about the selected **projects** and the **beneficiaries**.

12.2.4 Critical Mass objective achievement

Again, as the call is not yet closed it is difficult to evaluate the achievement of the CM objectives in this specific EN. Only one respondent answered to the question of the achievement of the objectives of CM and indicated that NB made a step forward to reach all of them.

However, we could stress some elements underlining positive expectations about the achievement of a CM:

- **Very few (and small) European regions are lacking in NB**: Mayotte, Wallis & Futuna in the French case, if one considers the target regions (inter-tropical ones). But all in all, especially at the institutional point of view, the critical mass is reached to the extent that most of participants are included.
- Whatever will come out of the call, NB is considered as a success by the partners having been able to work together. It is the **first time that Regions have cooperated to set up their own research programme.**
- NB is very important for the Regions involved to coordinate their activities and the project is crucial **to develop locally adapted solutions** to the problem of biodiversity.

NB generated the following impacts:

- **Creation of new networks**
- **New collaborations** inside and outside the EU
- **Opportunities for networking** with other programme managers and programme owners and European scientific communities across Europe
- **Mutual learning** about the design of joint activities between programme owners and programme managers, thus enabling transnational R&D cooperation creating a forum for discussing R&D policy and priorities in specific research fields at European level.

This table reports the answer of one respondent:

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-techn. Challenge	New processes, products and services; Access to new markets.	The most important indicators are witnessed	*Important for preservation and valuation of biodiversity*
Address scientific challenge	Additional researchers and higher position in international ranking	Publications/patents are not witnessed	*Important in terms of complementarity, multidisciplinarity and global approach of local problems*

Securing a level of competence (defensive)	Additional researchers, improved processes, new research contracts, new tra	Almost all most important indicators witnessed, but only new research contracts by more than one respondent. Some less important indicators expected by coordinator.	.
Securing a level of competence (prospective)	*Similar to defensive CM, but logically, it can only be one of them.*		
Reach Excellence	Additional researchers and higher position in international ranking	Not the most important indicators are witnessed.	*To become more visible internationally.*
Self-sustained dynamics	Cooperation with third parties, additional researchers, networking, increasing number of actors active in the field	The most important indicators are witnessed.	*Expect to create a snowball effect involving neighbouring regions and other third parties*

None of these CMs have been achieved currently, but the partners of NB have **created the conditions to be able to achieve them**. **Probably reaching self-sustained dynamics and addressing socio-technological and scientific challenges are the most important CM that will be achieved.**

12.2.5 Factors relevant for achievement or non-achievement

While we describe in section 2.1 possibly relevant environmental conditions and in section 2.2 possibly relevant determinants (activities), we arrive in sections 2.3 and 2.4 at the results and level of achievement. In this section we draw a first analytical conclusion from this case study about which of the above mentioned factors (either environmental conditions or something related to ERA-NET activities) appears to be a relevant factor for (non-)achievement of CM. The statements are based on the indicators or other evidence from the interviews in this case study.

- **Stability of personnel and learning abilities of Regions:** other barriers were underlined: administrative barriers, financial barriers, time difference between the islands, coordination issues, management of carrier of employed people, people involved in too many projects with little time to devote to NB, high turnover of personnel in the project. Linked to this latter aspect, since the ENs are limited in time and the regional institutions do not have large internal capacities, they have to hire personnel for the duration of the project. Then the capacity is developed by only one person who might leave the regional authority or even the region after the end of the project. So building institutional learning ability and absorptive capacity is really difficult. This is an aspect of the critical mass that has to be taken into account (critical mass at the level of agencies). Thus the objective to develop capacity of programme design and management is not necessarily achieved in the long run. In addition, it is important that the local policy-makers learn how to appropriate the EN framework. In general they know quite well the aims, logic and mechanisms of structural funds, but not those of the FP. For identifying and maximising the impacts and implications of EN in general in the "small regions", the policy-makers should be largely involved and supporting regional authorities and researchers.
- **Placing the responsibility on the territories and bringing research on biodiversity closer to the Regions**. One of the most novel elements is that NB pushed Regions to promote trans-regional cooperation. **Regions are managing biodiversity research with ownership and responsibility**. **Regions** will try to solve their problems and **get the benefits**, which could be

summarized as follows:

- ✓ Regions will be able to look at the problems with a more global vision is they cooperate instead of looking only at the regional level. For instance, they will be able to tackle climate issues in a global way
- ✓ Scientists will be induced to tackle the issue in a global way instead of considering the specific question at the regional level. This will also induce them to deal with more global issues.
- ✓ New stakeholders (the Regions) are getting involved in science and will derive large benefits.

12.3 Conclusions

The Regions involved in NETBIOME have succeeded in pooling 3.5 million € for one call. Some Regions could only provide a small amount of money which is not considered as enough by the scientific community. Without any help of EU funding adapted to the specific environment of ORs and OCTs it will be difficult for research teams to generate high value research results.

NETBIOME has succeeded in involved the major European actors in the field of tropical and sub-tropical biodiversity. As far as the EC attitude towards ORs and OCTs is concerned, on the one hand, there is a growing concern for "regional knowledge", but on the other hand there are still some problems. One is that the geographical dimension is not well considered as regards cost: cooperation cost is considered as too high, but it is absolutely unavoidable for so remote regions anyway. Some experts do not really know the field. Another aspect is that there are not enough coherence and coordination between DG Research, DG Regio and DG development. Activities covered by NB are exactly at the crossing of the three; for instance ORs and OCTs are treated differently for political reasons, whereas as regards research and social utility they face the same issues and problems. Some tools and mechanisms are not really compatible, and there is no evolution on that side. In the past OR and OCT were not considered, now they are considered but with too much specificity; there should be a way in-between. For that, critical mass in organizing research as it is done in NETBIOME will help gaining visibility and recognition.

In this field of research the questions is more about coordinating the research forces between the islands and the continent and opening up to third countries than about competition.

NETBIOME could be a means to create a snowball effect inducing participating countries to increase their level of participation to the calls, but also inducing partners to get involved in the call and enlarge the possibilities. Opening towards third party countries could also be a way to enlarge the scope and the scale of a programme and thus reaching critical mass.

13 The ERA-NET NEURON

13.1 Introduction

The NEURON project has initiated the integration of neuroscience research policies and programmes across Europe. It has created a network of the major funding bodies in this research area, and provided a structure through which they can coordinate their existing programmes and develop a joint strategy for future research.

The project started as a small group of highly motivated partners who are key actors in their respective research funding systems. It is coordinated by Germany's Projekttraeger im Deutschen Zentrum für Luft- und Raumfahrt (PTDLR) on behalf of the German Ministry of Education and Research (BMBF), which has bilateral cooperative agreements in this field with relevant organizations in Poland and Israel. The experience gained from these partnerships is the foundation for ERA-NET. NEURON also benefits from a previous support action (SSA) involving 4 funding bodies or project management organizations (DE, IS, LU, PL). The CA will network across 11 funding organizations, 4 of which are ministries. The NEURON consortium has created a detailed programme to reach its goals, including the following: workshops to exchange information on the topics specified in the work programme; a work exchange of programme managers; the development of standards in specific areas of programme management; as well as agreements on joint programme management procedures. Another objective is to prepare and implement joint or common calls for project and fellowship proposals.

Research Fields: Neuroscience
Sector: Life Sciences
Overlaps with other ERA-NETS: E-Rare (on rare diseases) – This is low as they have a focus on some rare neurological diseases and other (non-neurological) diseases, while NEURON covers all types of neurological diseases and other neuroscience topics.
Duration: 4 yrs in FP6 from 2007 to 2011, an FP7 proposal is in preparation
EC funding: 2 700 000 € (CORDIS)

11 members of 10 countries in the beginning:
Coordinator: Germany: Projektträger im Deutschen Zentrum für Luft- und Raumfahrt
List of partners:

12. Germany: Project Management Agency in the German Aerospace Center for the Federal Ministry of Education and Research BMBF
13. Luxemburg: National Research Fund
14. Poland: Ministry of Science and Higher Education
15. Israel: Chief Scientist Office, Israel Ministry of Health
16. Austria: Austrian Science Fund
17. France: National Institute of Health and Medical Research
18. Finland: Academy of Science
19. Sweden: Swedish Research Council
20. Romania: Ministry of Education and Research
21. France: French National Centre for Scientific Research
22. Italy: Ministry of Health

Entries/Exits: Now 20 participants from 13 countries. ES, UK and Canada joined.

This report is based on the following sources:

- Basic information from CORDIS
- Responses of coordinator and three participants to CRIMASS online survey *(status of 26-01-11)*
- In-depth interviews with the coordinator and three partners
- Beneficiaries answers (*not yet included*)

13.2 Critical Mass analysis

13.2.1 External factors and policy objectives related to Critical Mass

We understand "critical mass" as not being a goal in itself, but contributing to a policy objective, so the first step is to identify this objective using the assessments of the respondents and indicators describing some environmental conditions of the field.

According to the Coordinator and three participants the answers shows high agreement for two objectives (scientific challenge and excellence):

- "to address socio-technological challenge", here: neuro-degenerative diseases cause very high costs for health systems; can they be prevented or remedied?, this is also an issue of "healthy ageing" (1: coordinator)
- "to address scientific challenge": to better understand neurological phenomena and diseases (3: coordinator, 2 partners)
- "to reach excellence" (although DE is with UK the scientific top player in Europe, they expect even more excellence by collaborating): US is the benchmark (4: coordinator, 3 partners)
- "to reach self-sustained dynamics in the development of the area": very much understood as creating a durable structure of coordinating research (i.e. not at the level of researchers, but at the level of programme owners) (2: coordinator, 1 partner)

Secondly, the policy objectives related to CM can be determined according to peculiarities and environmental conditions of the area, as described by the respondents/ interviewees.

Neuroscience is a research field "already partly explored but with a lot of research going on and an increasing number of researchers-labs involved". There are many researchers, groups, and beneficiaries in the field. Most of them are internationalized for a long time and have already had international collaborations. Leading countries in Europe are DE, UK and FR, but also ES, IT. Worldwide it is US, Japan and UK. The research field "requires more intangible type of infrastructure such as database, archive etc" (cohorts and clinical trials). Moreover, it is heavily connected to ongoing research activities in other fields both, as user of the results from this research and as supplier of results. As regards market, it is connected to future and foreseeable markets.

Neuroscience is a field which addresses socio-technological challenges (i.e. "healthy ageing"). Therefore it is currently the subject of political interest. In 2008, the European commission started an **Joint Programming initiative on neurodegenerative diseases (Alzheimers, Parkinson,…) – JPND.** JPND has more member states on board and addresses rather the programme owners than the managers. A governance structure has now been defined. Calls are in discussion, further activities unclear. On top of that, there is now the Innovation Union initiative featuring European

Innovation Partnerships for its implementation. First activity is “Healthy ageing”. Again, it is unclear, what will happen in this framework, it shall encompass Joint programming and more. In NEURON, they are not really doing “joint programming”, they are only about to define some strategic priorities for the FP7 version, currently in its application stage.
Most obviously from these descriptions appear the following types of objectives (which have also been mentioned by the interviewees):

- “to address socio-technological challenge”
- “to address scientific challenge”
- “to reach excellence”
- “to reach self-sustained dynamics in the development of the area”: perhaps less applicable, as researchers have already international networks

13.2.2 Determinants of Critical Mass

The activity profile of an ERA-Net (activities related and not related to R&D) should give first indication on what kind of achievements can be expected. NEURON has many and large calls. On the side of non R&D activities they are doing among others an excellent paper award, despite financing is not easy to be organized (not foreseen in the scheme). Concluding from the weight there are giving to these activities, it can be expected that the scientific orientation of the activities result in addressing respective challenges or an increasing excellence.

- Joint activities: **They have one call per year, each call at about 10 mill. €, all virtual pot.** Only the first call had all partners on board, Later UK and SE missing.
- NEURON initiative has put together scientific communities which have not many possibilities to collaborate at transnational level, because of the lack of transnational programmes on that topics. The 2010 call has been very particular. Mental diseases not being a FP7 theme, this call put together different communities that never collaborated before, molecular biologists with chemists, and in NEURON II a second call on mental diseases will be launched.
- In NEURON, they are not really doing “joint programming”, they are only about to define some strategic priorities for the FP7 version, currently in its application stage.
- Among **non R&D activities**, an '**Excellent paper in Neuroscience' Award** for young scholars is the most peculiar. It is difficult to finance this activity, as the ERA-Net scheme does not include spending for this type of activity, however, they try to find a way and keep this activity running. (They also had a concept for training activities, but gave it up for the reason of difficult financing.)
- Others: Coordination of national projects: done by a survey, where they asked about national budgets and funded topics and similar, to be downloaded here (2 reports about national funding programmes, see: http://www.neuron-eranet.eu/en/108.php#National_funding_programmes). They have also a database on nationally funded projects (about 2000 of 10 countries). Clustering of national projects was intended first, but then they found, that a joint call is easier to implement than thought before, so they are now doing one call a year and clustering is not needed any more.
- Schemes for personnel exchange (at the level of programme managers): this was intended at first, but then they saw, that this was not any more necessary, as they had very quickly build up trust and a very good mutual understanding of each other work.

13.2.3 Components of Critical Mass

This section gives an overview on the different types of resources which have been pooled by ERA-Net activities. It also gives an assessment on the achievements of the exercise.

Critical Mass of Funding budgets:

- Coverage of relevant countries: They have many of the relevant (in terms of scientific excellence) countries on board. Of the relevant countries DK, NL and NO are missing, while with NL and NO there is some hope, that they might join the FP7 group. Turkey has indicated interest in joining.
- Beyond the countries mentioned, there will be no efforts to further enlarge, as they fear, that coordination of a larger group (say about 30 participants) will become more difficult.
- Only the first call had all partners on board, Later UK and SE missing. For UK the reason could be that they can be considered to have a critical mass of researchers (excellence) on their own. As for SE, it is less clear. Both countries are being represented by national research councils, not by programme managers, which gives perhaps a different view on things. While programme managers see also the political merits of the ERA-Net, the research councils are represented by scientists who have perhaps other priorities.
- Large pots (each about 10 mill €)
- Coordinator ranks activities as more than effective / excellent, as launching 4 calls was far beyond their expectation, and a midterm symposium was organised for the first joint call, with excellent feedback from funded projects.
- Virtual pot is being rated by the interviewees as effective. Comment: the need and excellence of the national research community and earmarked budget have to be matched. It is an issue – not only in the first call, that some partners initially earmarked too little. Solutions are jointly elaborated in order to ensure that all applications rated with an A can be funded.
- This collaboration prevents fragmented bilateral approaches of coordination.
- In Spain, ERA-Net responsibilities will be transferred from the international department to the technical department. This will be a benefit, because International cooperation will not lose touch with National Programmes and because of the budget, International budget is too low.

➔ Author's comment: Pooling of funding can be regarded as effective, despite UK and some other countries are missing, and despite there is the issue of countries earmarking too little, which has so far always been solved.

Critical Mass of Researchers:

- Coverage of relevant countries: They have many of the relevant (in terms of scientific excellence) countries on board. Of the relevant countries DK, NL and NO are missing, while with NL and NO there is some hope, that they might join the FP7 group.
- Large group of beneficiaries (10-11 projects per call, each having 3-5 partner groups).
- They have set a maximum to five research groups per projects in order to avoid large-scale projects. Minimum is three partners (from three countries).

- The beneficiaries selected are those expected to participate, i.e. the most relevant and excellent players in the field; mainly universities are eligible (and others, according to participants' criteria). In France, Era-Net could attract new beneficiaries not known by ANR.
- Very well-established common international evaluation procedure for proposals.
- Interesting: High-risk projects are welcome (although they do not flag it out explicitly in their calls, but they encourage reviewers in the evaluation stage of the applications to support high-risk research).
- They are expecting radically new results from the projects.
- Compared to the national calls of some respondents, the ERA-Net calls have by far a broader scope. Research teams can set topics bottom-up and this possibility is being used. In this context of doing research on "new" topics, also new research consortia have been set up.
- There is fairly significant evidence with respect to the access to foreign research communities (e.g. Canada).
- One partner said, that more ambitious projects and new type of research projects have been funded at national level. A significant evidence of access to foreign communities has been experienced.
- The coordinator does a monitoring of (excellent) output in order to report about success based on evidence to the EC.

➔ Author's comment: Positive indications clearly prevail. Except for the UK and some other scientific communities, the relevant researchers are part of the exercise.

13.2.4 Critical Mass objective achievement

In this section, we report how respondents assess the achievement of objectives and, secondly, how the level of achievement can be judged based on output indicators.

The first aspect is the direct response of the interviewees, i.e. their own assessment to which of the objectives related to CM they are witnessing or expecting any progress.

According to the coordinator's and the partners' assessments, there are some results related aforementioned objectives:

- "to address socio-technological challenge": Diseases addressed, however impact like elimination of diseases is long-term and not yet expected (coordinator)
- "scientific challenge": diseases addressed, many publications already (3: coordinator, 2 partners)
- "to reach excellence": many publications, excellent researchers have been participating in calls and have been granted projects (3: coordinator, 2 partners)
- "to reach self-sustained dynamics in the development of the area": if understood at the level of programme owners / national agencies there have been steps forward to implement a permanent European coordination structure (WP in FP7 version of ERA-Net planned) (2: coordinator, 1 partner)

Again, the respondents agree most on the objectives of addressing a scientific challenge and reaching excellence.

Secondly, we look at the list of output indicators as reported by the interviewees. We have mapped in a preliminary effort the output indicators to each of the different types of CM objectives, and can now do a check which CM type is best supported by the output profiles given by the interviewees. There are some discrepancies by the respondents, as can be seen in the table below.

Objective related to critical mass	*Output witnessed / expected*	*Level of achievement*	*Comment*
Address socio-technological challenge	New processes, products and services; patents.	Only one most important indicator mentioned by one respondent. Patents indicated by coordinator, while other important and less important indicators mostly missing.	*No real agreement by respondents.*
Address scientific challenge	Scientific publications, most cited publications, creation of access to new research fields	The most important indicators are witnessed / expected by all, coordinator sees additional evidence for other indicators.	
Securing a level of competence (defensive)	*n.a. according to section 2.1*		
Securing a level of competence (prospective)	*n.a. according to section 2.1*		
Reach Excellence	Scientific publications, most cited publications, patents, improved position in international ranking.	Most important indicators are witnessed / expected, but two of them only either by coordinator or one participant. Other indicators witnessed, too, however, there is also disagreement among respondents.	*There is evidence, but also some disagreement among respondents.*
Self-sustained dynamics	Patents, Scientific publications, additional researchers, networking	Many of the most important indicators are witnessed / expected, two of them by all. Two indicators of minor importance are witnessed, too, by coordinator.	*Has not been identified explicitly as an objective in section 2.1. There is some evidence with disagreement.*

Overall, addressing a scientific challenge is very clearly supported according to indicators. There is also evidence for reaching excellence and self-sustained dynamics, but there is more disagreement here. There is no real agreement by respondents about addressing a socio-technological challenge.

According, to the author's assessment, most important among these objectives seems to be addressing a socio-technological and a scientific challenge and reaching excellence, as they have been identified from the beginning by all participants as the major objectives. This is also clear form the fact, that they themselves value the respective indicators for the scientific CM types very high (academic returns and the excellent paper award). Moreover addressing a socio-technological challenge, has also been identified by the author (and the coordinator) based on the peculiarities of the field.

As has been shown, there is clear progress with respect to addressing a scientific challenge, and there is some progress with respect to excellence. Addressing a socio-technological challenge is not (yet) so clearly supported by the indicators, it is too early to tell, as understanding and healing diseases may take by far more time.

13.2.5 Factors relevant for achievement or non-achievement

While we describe in section 2.1 possibly relevant environmental conditions and in section 2.2 possibly relevant determinants (activities), we arrive in sections 2.3 and 2.4 at the results and level of achievement. In this section we draw a first analytical conclusion from this case study about which of the above mentioned factors (either environmental conditions or something related to ERA-NET activities) appears to be a relevant factor for (non-)achievement of CM. The statements are based on the indicators or other evidence from the interviews in this case study.

- **Individual rationales / national interests going beyond learning or networking:**
  - Many partners in favour of "Creating and supporting transnational projects in a field which requires transnational cooperation", i.e. a pooling of resources.
- **Engaged coordinator for the pooling of resources**:
  - Coordinator wants "Creating and supporting transnational projects in a field which requires transnational cooperation", i.e. a pooling of resources.
  - Participants evaluate coordinator positively.
  - The management approach is to be very precise and clearly structured. The coordinator dedicates more effort than funded by the EU to the management; and seems to do this very empathically. Finally, she intends to deliver in her reports clear evidence for success (so a rather "scientific" approach). To this end, she collects a lot of feedback from beneficiaries. For FP7 a regular monitoring is being planned.
  - In the course of the FP7 application, they foresee a workpackage on planning follow-up activity to the ERA-Net, i.e. to create a coordination structure independent of ERA-Net funding.
- **National representatives need to be political, i.e. they should see and convince their authorities at home of the potential merits of the collaboration and hence of the need to commit (more) funding.**
  - UK and SE are being represented in NEURON by national research councils, not by programme managers, which gives perhaps a different view on things. While programme managers see also the political merits of the ERA-Net, the research councils are represented by scientists who have perhaps other priorities. This might explain why UK and SE did not participate in any more calls after the first one.
  - In Spain on the other hand, ERA-Net responsibilities will be transferred from the international department to the technical department. This will be a benefit, because International cooperation will not lose touch with National Programmes and because of the budget, International budget is too low.
- **Well-focussed and continuous (R&D) activities NOT necessarily needed:** Compared to the national calls in some partner countries, the ERA-Net calls have by far a broader scope. Research teams can set topics bottom-up and this possibility is being used. Despite a lacking "joint programming", impacts relevant for the achievement of objectives related to critical mass could be achieved.
- **Critical Mass is <u>not</u> necessarily linked to increasing scale of projects**: They have set a maximum to five research groups per projects in order to avoid large-scale projects. Minimum is three partners (from three countries).

- **Opening up to the world can be a supportive factor:** Open up also for non-EU participation (here Canada is a big plus; US of course would have been interesting, too).

13.3 Conclusions

NEURON is very successful with the coordination in the field of neuroscience research. They have done four calls already, which is by far more than expected. Moreover, they have almost all relevant countries on board, and there is hope that others will join. The collaboration in the ERA-Net has an added value, as it clearly prevents states from bilateral cooperation.

They have pooled very large (virtual) pots, but there is still the issue, that some partners earmark too little (which so far could be solved at any time). Moreover, UK, who have a critical mass of excellent researchers on their own, are not any more taking part in the calls.

The group of beneficiaries reached by the ERA-Net calls is large, despite the fact that the size of projects is restricted to five partner groups in order to avoid coordination losses. This seems to work very well, as the outputs of the projects are quite promising.

It is not yet clear how the other European initiatives, the Joint Programming on neurodegenerative diseases and the Innovation Union initiative on “Healthy Ageing”, will be organised and how much thematic overlap there will actually be (e.g. NEURON is covering more than neurodegenerative diseases). However, NEURON has proved to achieve impacts relevant to critical mass objectives with a number of open calls, i.e. without a joint programming approach, which indicated that well-focused strategic and continuous R&D activities are not necessarily needed for reaching critical mass.

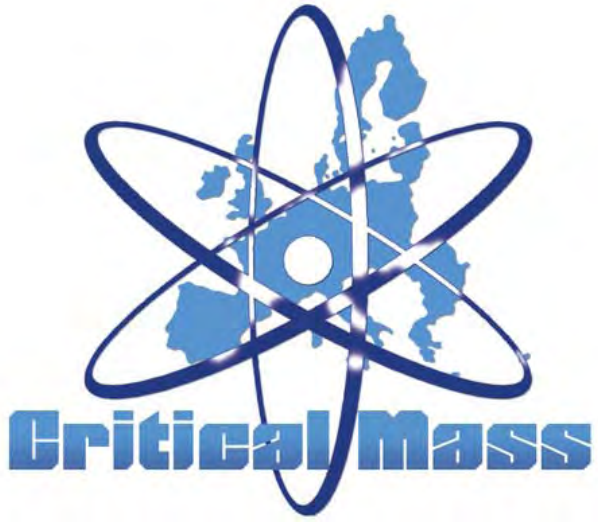
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Annex 3

The Relevance of Critical Mass and Coordination in Research Policies and Programmes in the USA, Brazil, Russia, India and China

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1 Introduction

This volume of the Final Report contains an overview of all relevant programmes that were identified in the US, Brazil, Russia, India and China. It includes sections on the respective innovation systems and innovation policies and presents in detail the various characteristics and specificities of programmes for coordinating research policies in the US and the BRIC. The goal is to assess whether these countries at stake show similar rationales for building up critical mass, what instruments they use to achieve this (compared to the ERA-Net scheme) and whether the definition of CM is valid in other contexts as well.

Given the sheer number of individual programmes in the countries at stake that might apply in the context of this study it was necessary to confine the analysis to a number of relevant programmes that show similarities to the ERA-Net scheme. As a result, all countries under review implemented initiatives for coordinating research ranging from joint programmes of different departments to joint funding and implementation schemes with sub-national units.

The goal of this comparative country study is to assess the indication of the relevance of critical mass in programmes of coordinated research outside the EU. This requires not only to identify relevant programmes and other measures designed to pool resources relevant for critical mass, but also to measure the level of achievement. In this stage of the work we focussed on the identification of programmes and qualitative information available about them. Even though it was possible to identify these programmes through an intensive literature review and a thorough investigation of online data sources (such as the ProInno Trendchart data base) it was not possible to come up with the same level of detail as with the ERA-Nets. Due to the lack of reliable and comparable data, in particular systematic programme evaluation, CM achievement can only be illustrated for some examples.

In another part of the project, we have approached this by analysing patent and publication output not only of European institutions, but also of institutions located in the US and the BRIC countries. This kind of analysis cannot causally link the observed output to certain policy measures, but it can illustrate the strengths of the countries and regions in different selected disciplines, i.e. it can show the level of excellence achieved by different research communities in worldwide comparison.

It should be stated at the beginning that there is no instrument comparable to the ERA-Net scheme in the BRICs Countries and the US. The ERA-Nets are a genuine EU initiative that is not applicable one to one in other national contexts since its main features are transnational policy coordination and joint funding mechanisms of research explicitly by more than one country. Transnational cooperation unarguably entails more stumbling stones and is more difficult to implement since it does involve the possible diverging interests of a given number of partners. Therefore it should be made explicit at the beginning that the comparison is not about the ERA-Net scheme as such but more about the ways that the competitors of the EU employ to generate critical mass.

Although we might well understand the European Union as well as the five countries included in the comparison as multilevel systems, they obviously are largely different with respect to the degree of centralisation of policies at the federal/supra-national level. The history of European integration is all about the effort to harmonize or centralize different national policies where the objectives to be addressed are too large or require too much effort in order to be reasonably addressed by approaches of individual countries alone. The political system of the USA, despite having developed differently, shows a similar degree of decentralisation of policy competences. In contrast, Brazil, Russia, India and China all have historically developed top-down structures. Apart

from these general characteristics, the EU and the countries under comparison have allocated policy competences differently between (federal) levels and focus moreover on different policy priorities, which influences the "starting point" for the comparison of research and innovation (R&I) policies in these countries. While the approach of the European Research Area (ERA) is to create critical mass in order to better achieve at R&I policy objectives, this tendency to centralisation is not the same for all analysed countries. We find aspects of centralising or integrated coordination of efforts in the US, Russia or India, while China and Brazil currently also show attempts to decentralized policies in order to strengthen regional development.

Another challenge for the comparison is the heterogeneity of the group of countries. While the US can be considered a major competitor in terms of scientific development, the BRIC still have a clear disadvantage in this respect towards the EU – at the moment one might add (see Annual Trendchart reports for the recent dynamic especially in China). During the course of the last decade these countries have been building up their scientific and innovative capacities and tried to complement their economic growth potential that was initially based on static competitive factors such as cheap labour (India and China) or natural resources (Brazil and Russia) with some more technological and science based factors. In this respect it also needs to be acknowledged that the BRIC are by no means a homogeneous group of countries (Armijo 2007) and each of them as different strategies and focus areas. The approach by India and Brazil for example is much more orientated towards social development (science as a matter to solve social challenges such as poverty, mal nutrition, health, etc.) than China. The heterogeneity among the countries makes the object of comparison blurry and difficult to assess.

Finally, a serious challenge for the comparison is the lack of comparable data. Desk research allows for the screening of available publications and accessing publicly available data bases. However, there is a certain smack to official data in certain countries since it is likely to be whitewashed in the absence of scientific evaluations. The study was also limited because of the fact that it was not possible to generate primary data or to conduct interviews with policy makers and other stakeholders in the selected countries. Without a doubt this step would have yielded more in depth insights into the rationales of EU competitors and it would have been possible to compare the results of the European study on CM with the programs and instruments used elsewhere. While this has to be left for future research, the present study was limited to desk research.

However, despite the wide range of difficulties there are several starting points for a comparison with the ERA-Net scheme and the output of the Case studies. All countries aim to support their science and technology sectors in order to reach some of the objectives that were defined being related to CM in this report. All countries analysed here have at least national research programs that aim to contribute to socio-technological and scientific challenges. Also there are signs of programs for excellence and self sustained dynamics.

Therefore, and in order to deal with the above mentioned difficulties, a multifaceted view on the countries was employed that takes into account current national science and technology plans and secondary literature. The goal of this literature review was to identify policy measures of the respective countries that aim at creating critical mass – either in the sense of the framework proposed here or in the view of the analyzed programme.

In order to guarantee for a certain degree of data comparability we analyzed Trendchart Country reports and opted for the Erawatch policy measure database to identify individual measures on the programme level to see whether they show a notion of critical mass or interesting forms of coordinating research policies or programmes, which have been operated in a defragmented way. However, it needs to be mentioned that the list of programs is far from complete and had to be

complemented with additional research. Because of the sheer mass of programmes the following chapters include a selection of programmes that appeared mentionable in the context of this study. The presentation of programmes includes those national programmes that support science and technology in terms of network creation and the different notions of CM as outlined in the analytical framework.

2 The United States of America

2.1 Introduction

2.1.1 Economic and political trends

The US economy with a population of about 300 million is now clearly smaller than the EU-27 with approximately 500 million inhabitants, but about 50 % more productive than the heterogeneous European economy with a GDP per capita at 48,000 US$ compared to about 30,000 US$ in the EU. The composite indicator from the European innovation scoreboard indicates that the innovation performance of the US exceeds that of Europe by 22 % (see Table 1). R&D expenditures were at 2.6 % of the GDP in 2006. In absolute terms, the US are the country with the highest R&D expenditures worldwide.

The recent mortgage and investment crisis has however harmed the US economy more severely than the EU with a deep recession since December 2007 with the GDP growth rate declining by 6 % in the end of 2008 and the beginning of 2009. The unemployment rate went up from 4.6 % in the end of 2007 to 5.8 % in 2008 and has become even higher in 2009, with significant job losses in all sectors, particularly in construction, industry and financial services. The negative impacts of the economic crisis on business innovation activities, especially private sector R&D, cause concerns about the effect of the current downturn on innovation.[1]

Population (Head count, 2008)	304.2 mill.
GDP per capita (in US$, 2008)	48,000 (est.)
GDP growth rate (2008)	0.42 %
Unemployment (2008)	5.8 % (est.)
R & D intensity (GERD/GDP, 2008)	2.77 %
Share of private sector R&D (2008)	67.3 % (est.)
Share of public sector R&D (2008)	27 % (est.)
Innovation Performance (innovation gap 2008 compared to EU-27)	+22 %

Table 1: Indicators for the US at a glance

Sources: OECD (2010) Country statistical profiles, CIA World Factbook, Eurostat,, Innovation performance data from EIS 2009

According to ERAWATCH monitoring, “significant recent political events that impact research policy include the September 11, 2001 World Trade Centre attacks and the wars in Afghanistan and Iraq. Following these events, more money was allocated to defence and homeland security, so there was less discretionary spending available for civilian research policy. In addition, more emphasis was placed on defence and energy related research. The economic downturn and credit crisis placed even greater priority on policies that can stimulate short-term economic recovery. The Presidential and Congressional elections in November 2008 signalled a major change in policy

[1] Youtie (2009).

priorities, including new priorities and support for research policy. Coupled with the current economic downturn, research policy is part of a group of programs designed by the Obama administration to stimulate the economy under the American Recovery and Reinvestment Act of 2009."[2]

2.1.2 Overview on USA's national innovation system

"The US innovation system is distinguished by its large size, diversity, federal structure, and competitive orientation."[3] Figure 1 depicts a schematic representation of the main actors in the industrial research system, the public research and education system, in the political system as well as actors which perform intermediary functions in the innovation system.[4]

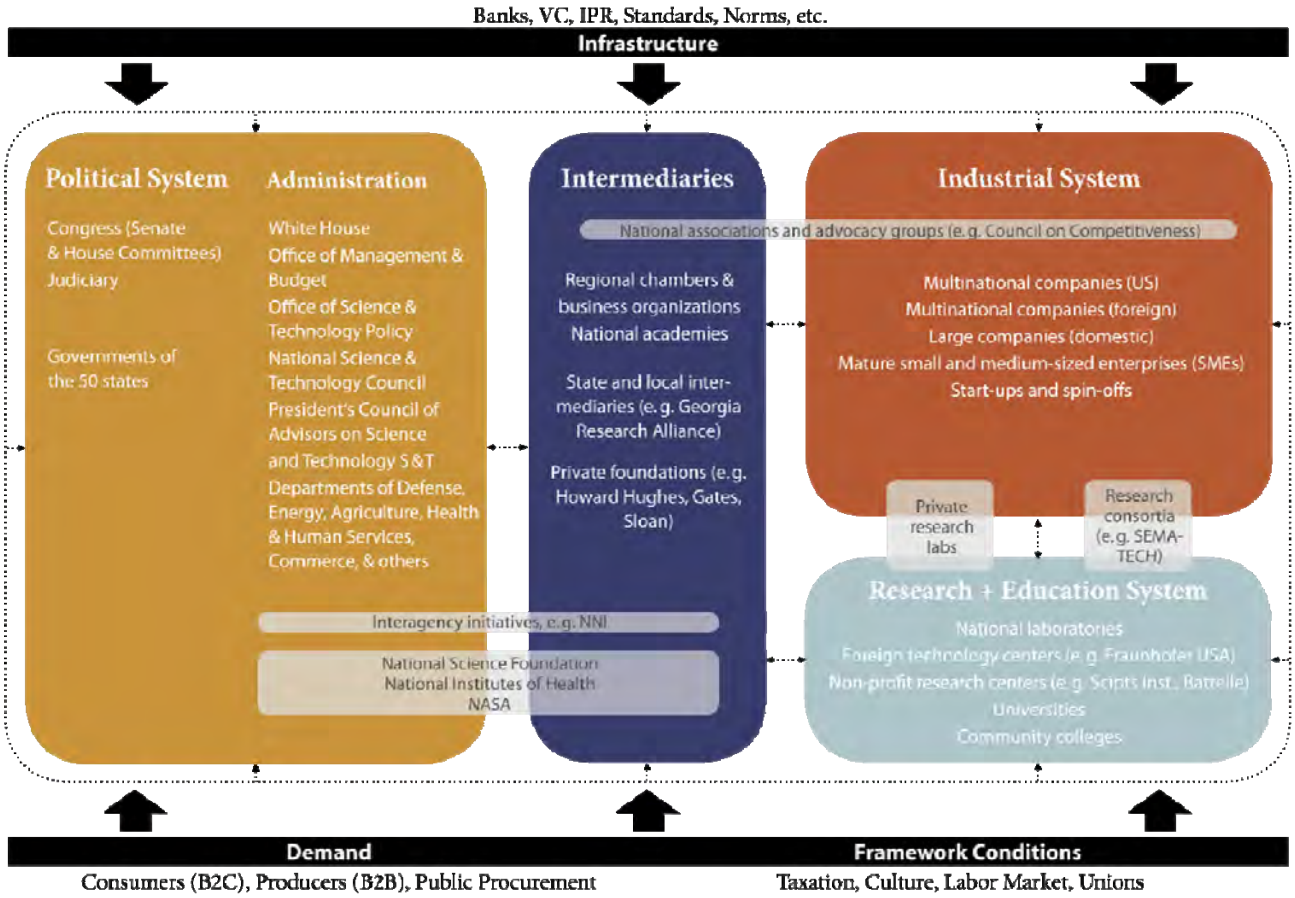


Figure 1: The US Innovation System at a glance[5]

Source: Own compilation

Like other innovation systems, e.g. the German NIS, the US system "has seen a transition from clear divisions of research labour to a blurring of boundaries."[6] Traditionally **universities**

[2] Youtie (2010), "Recent political events relevant to research policy".

[3] Shapira and Youtie (2008: 15).

[4] This kind of representation has its origins in the graphical illustrations of the national innovation system concept by Kuhlmann and Arnold (2001).

[5] Taken from Shapira and Youtie (2008: 16).

conducted basic training and research, while **large private sector labs** conducted applied research. Today, the **private sector** funds more near-to-product development than basic or applied research. Universities undertake applied research roles and are increasingly investing in technology transfer through licensing offices, incubators, joint programmes with industry or **university industry consortia**.

There are also multiple **intermediary** and technology transfer mechanisms in the US system including supplier-customer industry relationships (e.g. regional chambers and business organizations). Other intermediaries aim at policy advice and or advocacy activities by bringing together government agencies, business executives, university presidents, and other stakeholders. Examples of these types of organisations and intermediaries include the **Council on Competitiveness** and the National Academies.[7]

The **political and administrative system** is highly decentralized. As a very basic characterization, the federal level includes the US Congress which conducts policy making, has budgetary responsibility and provides oversight, and the US Office of the President and the executive branch of departments and agencies which develop policy, administer programmes, and adjudicate regulations. At the state level, the state governors, executive agencies, and legislative branches engage in similar activities to their national counterparts.[8]

The ERAWATCH monitoring describes the set of actors in the political and administrative arena at the federal level a bit closer: "The Office of Science and Technology Policy (OSTP) is located in the Executive Office of the President and has a mandate to advise the President and others on the effect of science and technology policy on domestic and international affairs. OSTP also acts as an inter-agency coordinating body. Funding through the federal departments and agencies in the executive branch occurs as a result of Congressional authorisations. The Executive Branch of the government includes 12 federal departments and 18 federal agencies that fund research. This funding is authorised by the US Congress. The top departments and agencies based on their R&D budgets are the Department of Defense, Department of Health and Human Services, NASA, Department of Energy, and the National Science Foundation. Several agencies operate research laboratories. For example the Department of Energy operates 10 national laboratories."[9]

Prominent expert committees that provide advice are the President's Council of Advisors on Science and Technology (PCAST) and the National Science and Technology Council (NTSC).

The main agencies for the implementation of research policy in the executive branch of government are:[10]

- The Defense Advanced Research Projects Agency (DARPA), which is a central research and development organisation for the Department of Defense (DoD),
- The National Institutes of Health, which is a main provider of health research activities as part of the Department of Health and Human Services

[6] Youtie (2010), "Basic characterisation oft he research system"

[7] Youtie (2010), "Basic characterisation oft he research system".

[8] Youtie (2010), "Basic characterisation oft he research system".

[9] Youtie (2010), "Brief description of the structure of the research system".

[10] Youtie (2010), "Actors in policy implementation".

- The Office of Science of the Department of Energy, which provides basic research in energy-related areas and manages the federal national laboratory system
- NASA, which implements the civilian space programme,
- The National Science Foundation, which implements the non-medical science and technology research and education policy.

The US innovation system is generally being considered to provide favourable conditions for innovation, including available private capital pools, adaptability of labour markets, favourable tax terms, as well as a legal and regulatory framework which is open towards innovation and stimulating innovators to take risks. [11]

2.2 Overview on the US research and innovation policies

2.2.1 Organization and main instruments

This section gives a general introduction into the policy-making of Research, Technology, Development and Innovation (RTDI) policies and programmes, the organisation between the federal levels and the main instruments of RTDI policy. The specific issue of coordination of sub-national policies is being dealt with in section 2.3.

Policy setting of the R&D agenda at the federal level comes through the budget process. R&D priorities are typically set by federal agencies based on their specific missions. Federal departments and agencies with the most substantial R&D expenditures include the Department of Defense (comprises roughly half the US R&D budget), Department of Health and Human Services (including NIH), NASA, Department of Energy, and the National Science Foundation. Coordination among these and other agencies is guided by memoranda on R&D priorities from:

- The Office of Management and Budget (OMB) which helps to prepare the President's budget,
- The Office of Science and Technology Policy (OSTP), which has primary responsibility for advising the President on science and technology policy, is involved in coordination efforts with federal departments and agencies, state and local governments, higher education, the private sector, other organisations that comprise the science community, and other nations,
- The National Science and Technology Council (NSTC), which is chaired by the President and comprised of the Vice President, the Science Advisor, and the chief executives of all federal departments and agencies with significant science and technology responsibilities. NSTC serves in interagency coordination and national goal-setting capacities,
- The President's Council of Advisors on Science and Technology, comprised of industry executives, university researchers and administrators, and chaired by the Director of OSTP, which provides advisory and evaluative assistance in science and technology areas.[12]

[11] Youtie (2009).

[12] Cited from Youtie (2010), "Government policy making and coordination".

The **main instruments** used to implement research policy in the United States are described below. In general, research policy is viewed more explicitly as a function of the US federal government over the last eight years, while there has been less support for major programmes employing federal funding to commercialise research outputs.[13]

- Generic R&D policy towards the public sector (e.g. competitive grants, large awards to create research centres),
- Generic R&D policy towards the private sector is aimed at fulfillment of mission-specific research. The Research and Experimentation Tax Credit is a primary fiscal tool for encouraging R&D in the private sector,
- Funding of multi-institutional, multidisciplinary centres of excellence or research consortia are instruments that are used to encourage linkage as part of research activities,
- Efforts to stimulate more scientists and engineers through scholarships, loan programs, and research assistantships,
- In terms of national R&D policy in the US, risk capital is typically left to the private sector. Some state governments have established seed capital funds to foster venture financing for start-ups,
- In contrast to the federal level, the state level sports multiple examples of programmes to foster innovation through building new applied research capabilities (e.g. Georgia Research Alliance).

2.2.2 Main objectives and major trends

In this section, the main objectives and major trends of research policies at the national level are being covered. The largest share of US R&D policy activities, as evidenced in the US R&D budget, are in thematic or "mission-related" areas, such as defence, life sciences, aerospace, and energy, while basic science comprises about 20 % of the US R&D budget. The research agenda has changed over time. "In the Clinton administration, greater emphasis was placed on health policy, the Bush administration saw enhanced emphasis on defence areas, and the Obama administration is increasingly focusing on energy and environmental areas."[14]

With the new Obama administration, it is now more likely to see the federal government in a more active role in research policies, also in response to the recent economic crisis. This includes a larger emphasis on research policy in the federal stimulus legislation. The current administration has reduced allocations to defence R&D by 4 % and increased allocations by 5 % to clean energy research in the research and development budget.

Changes in research priorities, and in the relationship between research and innovation policy, are suggested in the Obama administration's A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs.

[13] Youtie (2010), "Main instruments in research policy" and "Interaction between Innovation and Research Policies".

[14] Youtie (2010), "Policy mixes to stimulate research".

This document outlines the following current and future pathways:

- Increased investment in R&D as a percentage of GDP,
- Enhanced support for funding for physical and information technology infrastructure,
- Greater support for entrepreneurship, international trade and finance, and open government,
- Prioritised investment in clean energy, advanced vehicle technologies, health care technologies, and other society-driven innovation areas.[15]

2.3 The Coordination of Research Policies and Programmes in the USA

2.3.1 Introduction to ways and rationales for coordinating and pooling resources

This section shall give an introduction into the way the policies and programmes are organized at the national level, especially as regards coordinating research. It looks at trends towards centralization at the federal level and whether even the notion of Critical Mass appears as a rationale for research policies and programmes at the federal level.

Generally, the basic rationales of the US research and innovation policy clearly address the notion of generating critical mass – maybe not in explicit terms. However, the mission-orientation of the US policy, in particular the turn of the Obama administration towards societal challenges such as climate change, energy consumption, mobility, health care and similar, imply pooling a critical mass of resources. This is similarly true for the excellence orientation inherent in the US innovation policy.

The US funding system for R&D is highly decentralised and shared among multiple departments and agencies. The top departments and agencies based on their R&D budgets are the Department of Defense, Department of Health and Human Services, NASA, Department of Energy, and the National Science Foundation. The departments/agencies are running their own funding programmes according to their individual missions. In addition to this horizontal decentralisation, there is also a vertical sharing of competencies between the federal level and the states with the latter having individual innovation policy goals and measures. The coordination between the different actors is not as high as in centralized countries (like China), mainly because the US funding system is based on the principles of „checks and balances“.

Observers of the US innovation governance have seen a trend “in interagency partnerships and coordination at the level of the executive departments and agencies.”[16] The most prominent instrument in this context is the National Nanotechnology Initiative (NNI). The **National Nanotechnology Initiative** (NNI) is a cross-agency umbrella initiative that develops and coordinates R&D activities, participates in the setting of budgets, federal policies, and technology

[15] Youtie (2010), “Research policy trends”.

[16] Shapira and Youtie (2008: 20).

transfer. The **NIH Blueprint for Neuroscience Research** is a second example for the coordination of individual agencies' efforts and budgets in order to address societal and scientific challenges.

2.3.2 Selected Initiatives and Programmes

2.3.2.1 The National Nanotechnology Initiative (NNI)

In recent years, as nanotechnology has become more and more key to applications and products in many different sectors, the need to **coordinate research in this area between different departments and agencies at the US federal level** has grown very much. Having started as a loose cooperation in the mid-1990ies, the NNI has formally been set up in 2001. At that time the NNI involved six agencies, and it has grown to 23 participating agencies in 2005. Until the present, the nanotechnology budget has tripled and is now at **1.36 billion € per year**. The key activities of the NNI are funding research (in different programmes), providing support for the creation of university and government nanoscale R&D laboratories, stimulating the education of the workforce necessary for the future of nanotechnology, fostering cross-disciplinary networks and partnerships, disseminating information, enabling small businesses to pursue activities in nanotechnology, and coordinating nanoscale activities of federal agencies and departments.[17]

Compared to the ERA-Net scheme, the NNI **does not involve sub-federal actors**, but is a horizontal activity at the federal level, involving departments and agencies with nanotechnology R&D budgets (and some without budget). According to the information available, it seems to be the case that the **NNI coordinates the full budgets** of the participating institutions for this sector, while in ERA-Nets the partners can commit a certain share of their funding. The NNI clearly aims at **reducing duplication of research and making a better (synergetic) use of infrastructures**. The level of the calls remains national, so the motivation to open access to new research communities (in other countries) is not applicable to the NNI.

Evaluation and Impact: The programme is being rated according to Program Assessment Rating Tool (PART) on an annual basis as part of the budgetary process. The rating seems to be positive, as the funding continues and increases. Moreover, in 2005 a mid-term review by the President's Council of Advisors on Science and Technology (PCAST)[18] has drawn several conclusions which reflect that the NNI is based on objectives similar to those of ERA, hence there is an implicit approach to reach **critical mass** to contribute to the following objectives. For some of these objectives, there is some evidence of achievement:

- The NNI has taken steps to address societal concerns, e.g. environmental, health, safety,
- There is a scientific challenge: exploring the potential application of nanotechnology to different fields (and there is evidence of publications and patents addressing it),
- Excellence/Securing a level of competence for defensive reasons: "Today, the United States is the acknowledged leader in nanotechnology R&D. Our leadership position, however, is under increasing competitive pressure from other nations as they ramp up their own programs",

[17] Youtie (2010), "National Nanotechnology Initiative (NNI)".

[18] PCAST (2005).

- GENERAL: The study spells out the need to **increase coordination with the states** (who are offering additional R&D funds to nanotechnology). This would also increase similarity with the ERA-Net scheme.

2.3.2.2 Manufacturing Extension Partnerships (MEP)

Manufacturing Extension Partnerships (MEPs) are offered across the United States to manufacturing companies in order to help them to accelerate innovation and thus growing in size and competitiveness. They are private-public partnerships involving federal and state level agencies as well as business associations. They are offering services, such as training, tools, and connections to apply new technologies.

Compared to the ERA-Net scheme, MEPs do not offer research funding.

Evaluation and Impact: MEP sponsored a study conducted by the National Academy of Public Administration (NAPA) in 2004 which found that the program was well run and effective. However, it judged the MEP to be too oriented toward cost savings and lacking in enough services to foster innovation.[19]

2.3.2.3 NIH Blueprint for Neuroscience Research

The National Institutes of Health (NIH) are the national agency for medical research and a part of the Department of Health and Human Services which has the largest R&D budget for civilian research. The NIH Blueprint for Neuroscience Research is a cooperative effort among the 16 NIH Institutes, Centers and Offices that support neuroscience research. By pooling resources and expertise, the Blueprint identifies cross-cutting areas of research, and confronts challenges too large for any single Institute or Center. During each fiscal year, the partners contribute a small percentage of their funds to a common pool. Since the Blueprint's inception in 2004, this pool has comprised **less than 1 % of the total neuroscience research budget of the partners** which refers to about **100 million €**.[20] In 2009, the Blueprint Grand Challenges were launched, a research agenda which addresses three **major challenges**, which are in the first place of **scientific** character, but address also **societal** challenges.

Compared to the ERA-Net scheme, the NIH blueprint **does not involve sub-federal actors**, but is a horizontal activity at the federal level, involving the relevant medical institutes for neuroscience research. Similar to ERA-Nets, the partner institutes commit funding to a common pot, in order to support common research needs. The NIH blueprint has the mission to address challenges which are too big to be tackled by institutes' individual approaches. In the calls, also non-domestic (non-U.S.) entities (foreign organizations) are eligible for funding, however, the whole measure is not being flagged out as a means to increase international collaboration.

Evaluation and Impact: There is no evaluation study available so far. Overall, this is a promising approach however, the common pot of the cooperation comprises less than 1 % of the participants' budget. There are 22 closed calls listed on the webpage, and for 12 calls there are reports about awarded contracts, in total 55. Other evidence is not yet available.

[19] ProInno Policy Trendchart (2011).

[20] See http://neuroscienceblueprint.nih.gov. Own calculation of budget based on NIH enacted budget for 2010.

2.3.2.4 Basic Behavioral & Social Science Opportunity Network (OppNet)

The mission of OppNet is to pursue opportunities for strengthening basic behavioral and social science research (b-BSSR) at the NIH. OppNet prioritizes activities and initiatives that focus on basic mechanisms of behavior and social processes; that are **relevant to the missions and public health challenges** of multiple NIH Institutes, Centers and Offices (ICOs).[21] Founded in 2009, almost all NIH Institutes and Centers (ICs) collectively fund and manage OppNet over an initial five-year period with a budget of about **8 million € per annum**. Coordinated by the Office of the Director they integrate existing NIH efforts, target research **challenges best met collectively**, and collaborate on new research initiatives in complementary scientific areas. OppNet will also develop a plan for focused multi-year programs to advance priority topics within b-BSSR.

Compared to the ERA-Net scheme, OppNet shows the same features like the NIH blueprint. It **does not involve sub-federal actors**, but is a horizontal activity at the federal level, involving the relevant institutes. Similar to ERA-Nets, the partner institutes commit funding to a common pot, in order to support common research needs. The NIH blueprint has the mission to address **societal or scientific challenges** which are too big to be tackled by institutes' individual approaches or issues of interest to all institutes in order to **avoid duplicate research**.

Evaluation and Impact: In the first year after its inception, OppNet funded already 60 projects. Other evidence is not yet available.

2.3.2.5 Clean Energy States Alliance (CESA)

States across the U.S. with established clean energy funds or programs have banded together to promote clean energy technologies. Clean Energy States Alliance (CESA) is a nonprofit organization established in 2002 and comprised of 18 states with clean energy funds/agencies; it provides information and technical services to its members and works with them to build and expand clean energy markets in the United States. It enhances this collaborative network by **coordinating state efforts, leveraging funding for projects and research, identifying challenges** and solutions, and assisting members in program development and evaluation. Through CESA, the state renewable energy programs also are creating new partnerships with federal agencies, regulators, and industry to **encourage multilateral efforts** to accelerate clean energy progress.[22] Its budget comprises roughly **250 million € per year**, although it is not clear how much of this is invested in R&D activities. There is also no information available how much the member organisations have committed to the CESA budget compared to their individual clean energy funds.

Compared to the ERA-Net scheme, CESA shows similarities as it aims at **coordinating state level activities in a field which requires joining forces** in order to reach an impact. However, it remains unclear how much of this activity is devoted to R&D and to the creation of new knowledge and improvement of technologies.

Evaluation and Impact: Information about impact is not available.

2.3.2.6 Integrated Federal Energy Policy

The US government currently reviews its federal energy policy. In November 2010, the President's Council of Advisors on Science and Technology (PCAST) delivered its energy report, where it

[21] See http://oppnet.nih.gov/.

[22] See http://www.cleanenergystates.org.

suggested to pave the way for a more integrated federal level energy policy.[23] They see first the need to coordinate horizontally between departments, because "energy policy" is an amalgam, and often derivative, of policies for environment, competitiveness, security, finance, land use, and more (PCAST 2010: vii). **Coordination with actors of the sub-federal level is not planned** to take place in an institutionalised way. Instead there shall be a consultation process involving the Congress, the Energy industry, academia, state and local governments, nongovernmental organizations, and consumers. PCAST recommends to finance this new effort by spending additional federal funds. Secondly, the federal government should realign existing Energy subsidies and incentives in order to fit with the new priorities and use its purchasing power to advance energy innovation. Overall, **8 to 11 billion € shall be spent per year**.

Compared to the ERA-Net scheme, the coordination of energy policy at the federal level is supposed to be a **realignment of federal activities and budgets**, rather than a pooling of sub-national efforts. However, the **rationales** are well comparable to those of ERA, i.e. addressing issues of **competitiveness and societal challenges** (PCAST 2010: vii):

- Economic competitiveness: renewal of our own energy infrastructure and access to rapidly growing global markets for clean energy technology,
- Environment: rapid progress towards lower-carbon energy in this decade as a prudent response to global warming risks, and
- Security: scaling-up of technologies that reduce oil dependence and thereby improve both our balance of payments and our security posture.

2.3.2.7 Cross-state and regional coordination initiatives

The **State Science and Technology Institute (SSTI)** is one public-private organisation serving as a clearing house and information mechanism for federal and state research and innovation activities. Activities of the SSTI are not dedicated to a specific research field, but to all topics which contribute to economic growth through the advancement of science and technology. Research and innovation **funding activities are rather small**. Each year they fund the Award for Excellence in Technology Based Economic Development.

Compared to the ERA-Net scheme, the STTI does offer research funding only at a very small scale. It is not thematically focussed and its major goal is economic development.

The "Southern Growth Policies Board, which was created as an outgrowth of efforts to enable the US South to emerge from lagging economic circumstances and the economic depression of the 1930s, created the **Southern Technology Council (STC)** in 1971 to foster research and science-based connections among its 13 member states and to give the regions a bigger say in respect to research and innovation developments at the national level."[24] Activities of the STC are not dedicated to a specific research field, but to all topics which contribute to economic growth and societal life. Research and innovation **funding activities are rather small**. They finance one or two research fellows per year and launch the Southern Growth Innovator Award each year.

[23] PCAST (2010).

[24] Youtie (2010), "Policy making and coordination".

Compared to the ERA-Net scheme, the STC does offer research funding only at a very small scale. It is not thematically focussed and its major goal is regional development, however it also addresses societal challenges.

The **Appalachian Regional Commission (ARC)** is a regional economic development agency that represents a partnership of federal, state, and local government. Established by an act of Congress in 1965, ARC is composed of the 13 Appalachian states. Local participation is provided through multi-county local development districts. ARC funds projects addressing the creation of new jobs, development of infrastructures and increasing overall competitiveness, of which only a small number are research projects. In 2010, 7 out of 60 projects were research projects with an overall budget of about 0.5 million €.[25]

Compared to the ERA-Net scheme, the ARC does offer research funding only at a very small scale. It is not thematically focussed and its major goal is regional development.

[25] See http://www.arc.gov

3 Brazil

3.1 Introduction

3.1.1 Economic and political trends

The Federal Republic of Brazil consists of 26 states and a federal district and has short over 190 million Inhabitants. The political situation in Brazil has been stable in recent years. The second government of current President Luis Inácio "Lula" da Silva was somewhat successful in dealing with some of the country's most pressing problems such as fighting poverty and pervasive income inequality. The remaining months of 2010 will be overshadowed by the presidential elections in fall in which President Lula despite one of the highest approval ratings in the region may not run again.

Population (Head count, 2008)	192 mill.
GDP per capita (in US$, 2008)	10,300 (est.)
GDP growth rate (2008)	5.1 %
Unemployment (2008)	7.9 % (est.)
R & D intensity (GERD/GDP, 2008)	1.13 %
Share of private sector R&D (2006)	ca. 45 % (incl. State owned firms)
Share of public sector R&D (2006)	ca. 55 %
Innovation Performance (innovation gap 2008 compared to EU-27)	-55 %

Table 2: Indicators for Brazil at a glance

Sources: OECD (2010) Country statistical profiles, CIA World Factbook, R&D statistics from OECD and Brazilian Ministry of Science and Technology (MCT), Innovation performance data from EIS 2009

Economic growth was stable but moderate with an average growth rate of 4 % between 2000 and 2008. The economic dynamics were spurred by internal dynamics and favourable external conditions. Being an export oriented economy Brazil's external trade was hit by the global downturn in 2008/09 especially because of falling prices for low-scale manufactures and primary goods. In 2008 the trade balance was slightly positive (15 billion US$, compared to 46 billion in 2006).[26]

Compared to the OECD countries, Brazil remains a low R&D performer. The country spends roughly 1.1 % of its GDP on S&T. There has been a significant rise in expenditures in the last few years in absolute terms but taken together the innovative capacity of Brazil is comparatively low.

3.1.2 Overview on Brazil's national innovation system

The Brazilian NIS is dominated by the federal government. Roughly 70 % of the country's spending on S&T stems from governmental sources. The Ministry for Science and Technology (MCT) is the leading ministry and, together with the Ministry of Education (MEC) and the Ministry for Development, Industry and Foreign Trade (MDIC), responsible for designing and implementing the country's ST&I policies. The MCT and its main agencies, the Brazilian Innovation Agency (FINEP)

[26] WTO (2010a)

and the National Council of Technological and Scientific Development (CNPq), are responsible for carrying out the largest share of national science programs.[27]

Some 60 % of GERD is directed towards the universities. Other important sectors include agriculture and health. Universities are *the* central actors for the creation of knowledge. The higher education sector in Brazil revolves around a few institutions that were initially conceptualized as pure research universities. The research system is concentrated in the states of São Paulo and Rio de Janeiro. Many highly regarded and highly specialized research institutes are associated with these universities, which include the *Instituto Nacional de tecnologia, Instituto Nacional de Pesquisas Espaciais* or the highly respected Fiocruz. The scientific community strongly influences the political decision-making process. The incentive structure is based on autonomy, scientific (not applied) research, coercion to publish and explicitly not on interaction with others (Stehnken 2010).

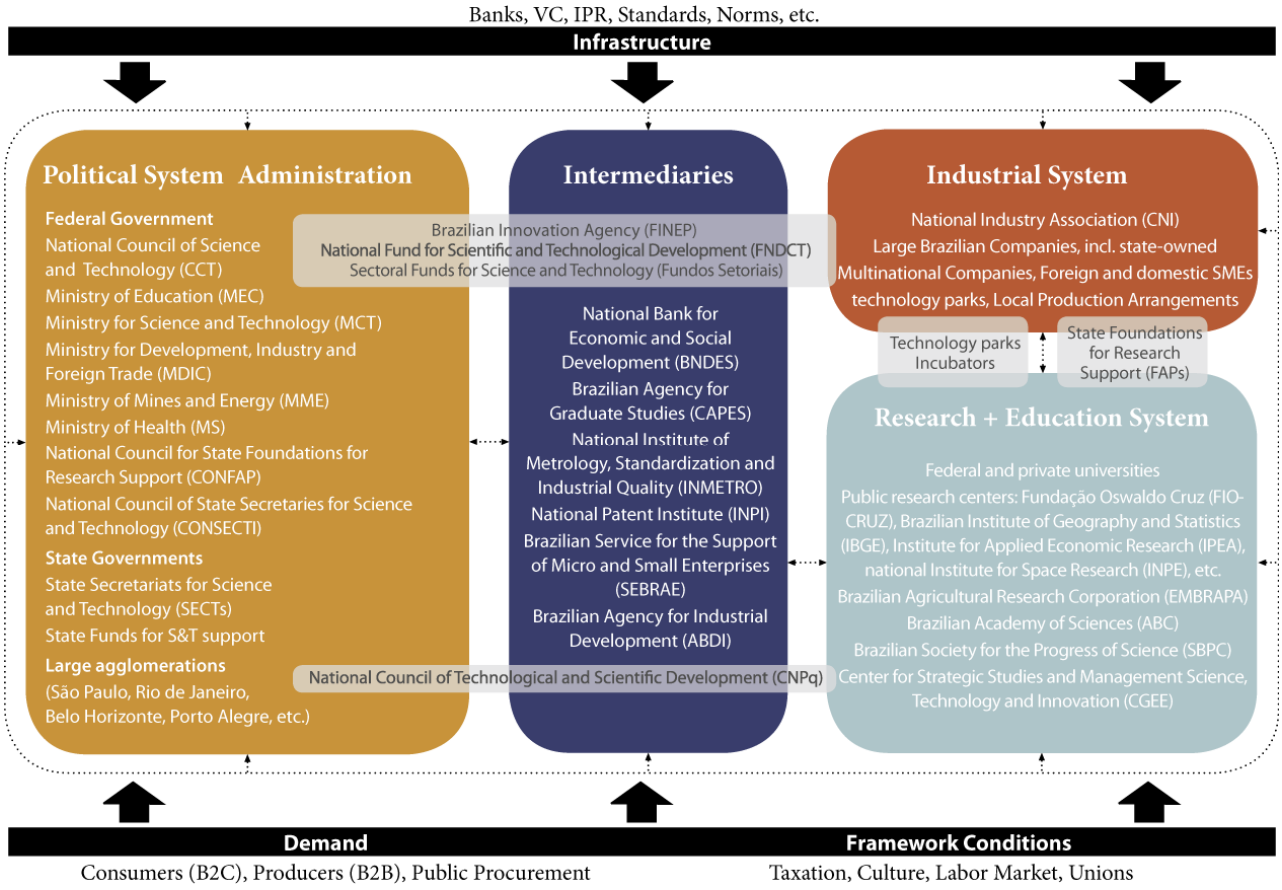


Figure 2: The Brazilian Innovation System at a glance

Source: Own compilation

Brazil's industrial structure is mainly made up of small- and medium-sized companies. This group of firms accounts for roughly 95 % of the total. They have serious difficulties to engage in innovation activities because they lack both manpower and financial resources to do so. Innovative activities strongly correlate with firm size. The last innovation survey (PINTEC) reported that only 1.7 % of Brazilian companies innovate and seek product differentiation; 21.3 % are

[27] Botelho (2009)

specialized in standardized products and 77 % carry out only little differentiation and show little progress in productivity.[28]
Traditionally, small as well as large Brazilian firms have relied heavily on publicly generated knowledge. Compared to the OECD world, internal or firm-specific R&D is relatively low. Regarding large companies the emergence of the so-called *multi-latinas* at the beginning of the new millennium onward reflects a new trend based on internationalization of business as well as research activities.

3.2 Overview on Brazilian research and innovation policies

3.2.1 Organization and main instruments

The MCT is the most important formal actor in ST&I policy-making. Nonetheless, the MCT is not to be regarded a first line ministry such as Social Security, Health or Education. Due to its crosscutting character, almost all other relevant ministries have some sort of support program in the area of ST&I, most notably, of course, MEC where CAPES is an extremely important institution in the higher education domain since it grants research scholarships. The MDIC that is responsible for defining the Industrial, Technological and Foreign Trade Policy (PITCE) via the novel Brazilian Agency for Industrial Development (ABDI) is also very influential. FINEP is the most important federal organization to support R&D. FINEP manages a wide variety of support lines and its incentives are the most multifaceted of federal incentives. For the most part, FINEP works with competitive calls, subsidies for researchers in firms and financial support for innovative product and process development.[29]
A current initiative to modernize and to strengthen the NIS is the determined Action Plan for Science, Technology and Innovation PACTI 2007 - 2010, which was presented by the Lula government as a cornerstone in an effort to modernize ST&I policies.
Even though there are numerous programs, countless incentives and public research organizations for all kinds of specific areas, the overall innovative performance of Brazilian firms remains low.[30]
As important as they definitely have been, political efforts of the past did not lead to a significant qualitative change of the industrial structure. However, in recent years the rules of the game have been altered by the implementation of various new laws that, on the one hand, aim to simplify the incentive structure by focussing on the actual costs for innovation instead of on a certain project (tax incentive via the Lei do Bem) and, on the other hand, to provide a legal basis for the cooperation between public and academic research and the private sector (*Lei de Inovação).*[31]
On the institutional level it can be concluded that the most important governance structures since the mid-1980s have not been altered in any significant way. "It remains a largely opaque, top-down governance structure"[32] that from time to time incorporates new regional, sector and research organization actors at lower levels of policy design.

3.2.2 Main objectives and major trends

The PACTI aims to spend roughly R$ 41 billion (approx. 14.3 Bio €) during the 2007-2010 period on S&T by joining efforts of several ministries and other public institutions. The key messages of this

[28] Arbix (2007)
[29] Botelho (2009)
[30] Arbix (2007), de Morais (2008)
[31] Botelho (2009)
[32] Botelho (2009)

publication revolve around four strategic priorities composed of all in all 21 lines of action and 88 programs and policy initiatives.[33] The priorities are:

- Expand, modernize and consolidate the NIS acting jointly with state governments to expand Brazil's science base (expansion and consolidation of national ST&I system),
- Accelerate the development of more favourable conditions to increase R&D in domestic enterprises thus fostering PITCE (promotion of technological innovation in firms),
- Increase innovation efforts in areas of strategic national interest such as energy, aerospace or the Amazon (promotion of ST&I in strategic areas),
- Universalizing access to science and increase diffusion of technology for better living conditions (ST&I for social development).

Acknowledging the weaknesses of the national innovation system that have been outlined above, the actual concrete goals of PACTI are the following:

- Increase domestic spending from 1.02 % of GDP in 2006 to 1.5 % by 2010,
- Increase private sector participation in total R&D spending to 0.65 % of GDP by 2010 (from 0.51 % in 2006),
- Increase the number of doctoral degrees granted per year and increase the number of scholarships granted by CNPq from 65,000 in 2006 to a least 95,000 in 2010, focusing on engineering and related areas.

Today's innovation policies need to be seen in the light of the new Industrial, Technological and Foreign Trade Policy (PITCE) announced in 2003 as an inter-ministerial strategy to increase Brazilian value added in international trade given the large share of primary goods and low tech manufactures in its export portfolio.

Brazil export structure includes transport material (i.e. EMBRAER commuter planes), chemicals, machines and equipment go along with traditional primary good exports such as oils and fruits, ores and meat. This diversity demonstrates that (1) the Brazilian economy is not organized around a specific economic sector for which its international vulnerability is limited, (2) the economy is only competitive in certain technologically sophisticated sectors, and (3) the capabilities in high-tech are rather low.[34]

Following the outline of PITCE, increased innovation becomes fundamental for the Brazilian industrial base in order to catch-up with international product and production standards and to manage dealing with international innovation competition. Taken together, PITCE revolves around five main issue areas that can be summarized as follows:

1.) Promote industry competitiveness,
2.) Expand access to markets and sectoral competitiveness to traditional industrial segments,
3.) Support the development of industrial pools of products with higher value added and technological content,
4.) Encourage R&D activities, creation and development of new technologies, and
5.) Increase exports and induce competitive replacement of imports, in order to reduce excessive external exposure of Brazilian economy.

[33] see for the following Botelho (2009)

[34] Stehnken (2010)

The PITCE has no own exclusive mechanism to approach the goals outlined above. Instead, the Ministry for Development, Industry and Foreign Trade (MDIC) as coordinating ministry aims at integrating various existing initiatives. What is at stake is a more coherent PITCE that inevitably needs a better articulation between the private sector, federal ministries and executing agencies to strengthen the efficiency of these policies. The implementation of such complex policies requires strategic collaboration and the creation of specific institutions.[35] Especially SMEs were not explicitly targeted by Brazilian ST&I policies. Given their size and their often traditional production structure, SMEs are locked in a situation of low techno-economic competence and low tech production. The Lula government made significant progress in this respect, but still could not bring the myriad of SMEs to embrace innovation.[36]

3.3 The Coordination of Research Policies and Programmes in Brazil

3.3.1 Introduction to ways and rationales for coordinating and pooling resources

As was outlined above, the Brazilian Innovation System experienced a considerable growth due to the expansion of public funds in recent years. The PACTI 2007-2010 was the most massive investment program in the history of Brazil's ST&I-System. During that period, many public programmes for coordinated research have been either expanded, re-designed or build up from scratch. Due to its crosscutting character, almost all other relevant ministries apart from the MCT have some sort of support program in the area of ST&I, most notably MEC and MDIC.

At the time of writing this report Brazilian politics is in a state of flux which holds also true for the country's ST&I policies. At the end of 2010 the two term president Lula da Silva had to step down despite high approval ratings and handed the presidency over to his long term colleague Dilma Roussef. All of the federal ministries have been replaced with a new team including the MCT and also the PACTI expired in 2010. It remains to be seen whether the policies of the Lula administration will continue or if the new government will implement new guidelines and strategic goals. Therefore, the programs laid out below reflect the policies of the former government.

Interestingly the strategy document for PACTI mentions "Critical Mass" explicitly as one of the guiding principles of the future strategy. The term is not defined at all but is used to describe the growth of the S&T system over the year, mainly referring to the currently 85,000 high-level scientist and engineers who carry out scientific and technological research of international importance and the growth in scientific publication out-put. These developments reflect a strong growth in Brazil's academic base. In the Brazilian context the notion of critical mass therefore mainly refers to a scientific or socio-technological challenge and is usually measured in term of publication and scientific awards or new products and processes.

3.3.2 Selected Initiatives and Programmes

Since ST&I policies are an interdisciplinary cross-cutting policy field, an important factor influencing coordination among ministries relates to the existence of multiple agencies with overlapping jurisdictions and the existence of a parallel bureaucracy (Hart 2001). As many ministries and their respective research organizations are involved in the coordination establishing

[35] Suzigan and Furtado (2006)

[36] Stehnken (2010)

a coherent ST&I policy is already a challenge on the national level. This is definitely a difficulty in the Brazilian institutional setup.
The various ministries and institutions traditionally lack interaction and ministerial co-operation tends to be difficult (Stehnken 2010). According to Botelho (2009), the political system has not fully kept up with the impressive changes in requirements for ST&I policy. This is true especially with regard to the newly required set of institutional arrangements among key players and organizations, such as the increased needs for monitoring and evaluation, the innovation-specialized human resources and the sharing of accountability (ibid.).
In the light of these needs, the MCT was looking for new institutional models and forms to produce science and technology. The strategic areas that were selected as lines of action in the PACTI are:

- Areas of future importance: Biotechnology and Nanotechnology,
- ICT,
- Health supplies,
- Biofueles,
- Electrical Power, Hydrogen and Renewable Energy Sources,
- Oil, Gas, and Coal,
- Agribusiness,
- Biodiversity and Natural Resources,
- The Amazon and the Semi-arid Region,
- The Weather and Climate Change,
- The Space Programme,
- National Defence and Public Safety.

3.3.2.1 The National Fund for Scientific and Technological Development (FNDCT) and the Brazilian Innovation Agency (FINEP)

The support of innovation and technological upgrading in SMEs is the task of the Brazilian Innovation Agency FINEP (Financiadora de Estudos e Projetos). FINEP is the most important federal organization to support corporate R&D and manages a wide variety of support lines. Although being a funding organization FINEP acts as the managing organization of the National Fund for Scientific and Technological Development (FNDCT) which is a mechanism to stimulate R&D throughout the country. The fund aggregates resources from various budgetary and non-budgetary sources which are then transferred into programmes. The FNDCT intends to ensure the expansion and stability of funding for S&T.
For the most part, FINEP works with competitive calls, subsidies for researchers in firms and financial support for innovative product and process development. Apart from the competitive call mechanism, FINEP is also involved in the process and payout of the incentives provided by the Lei de Inovação and Lei do Bem as well as other lines of support such as the Sectoral Funds (Fundos Setoriais, see below). It is claimed that the instruments and programs of FINEP need an extensive and long overdue review and simplification (Salerno/Kubota 2008).

Program/ Open Call	Arrangement of financial support	FINEP resources (million R$ and €)	Total resources in million R$ and € (1)	No. of supported companies	Average amount per company (1000 R$ and €)	Source
Pró-Inovação	Financing of expenditure for innovation– medium + large companies	1653.2 (552.9 €)	1653.2 (552.9 €)	142	11,600 (3879.6)	FAT-FND and CT Verde-Amarelo
Juro Zero	Financing of investments for innovation – micro + small companies	26.1 (8.73 €)	26.1 (8.73 €)	46	567 (189,6 €)	FAT and CT Verde-Amarelo
Pappe Subvenção	Subsidy for the cost of innovations through state and local institutions	150 (50.17 €)	245 (81.94 €)	- (2)	-	FNDCT and state institutions
Subvenção a Empresas	Direct subsidy for the cost of innovations	279 (93.31 €)	279 (93.31 €)	148	1885 (630.43 €)	FNDCT
Subvenção a Empresas	Direct subsidy for the cost of innovations	313.8 (104.68 €)	313.8 (104.68 €)	174	1803 (603.01 €)	FNDCT
Pesquisador na empresa	Subsidy for salaries of newly contracted researchers	60 (20.07 €)	60 (20.07 €)	125	480 (160.54 €)	FNDCT
FINEP/ Sebrae/ ICTs (Public call)	Non-reimbursable resources for running costs and capital expenses (for ICTs)	13.3 (4.45 €)	26.6 (8.91 €)	295	90.2 (30.17 €)	FNDCT and Sebrae
FINEP/ Sebrae/ ICTs (Public call)	Non-reimbursable resources for running costs and capital expenses (for ICTs)	20.8 (6.96 €)	41.6 (13.91 €)	420	99.1 (33.14 €)	FNDCT and Sebrae
Total		2516.2 (841.53 €)	2645.3 (884.72 €)	1162		

Table 3: MCT/ FINEP, Credit lines, subsidies and non-reimbursable concessions - resources and number of supported companies during 2005/2007

Source: Translated and with minor adaptations cited from de Morais (2008: 91)

(1) Includes resources and counterparts of partner institutions in the respective programs

(2) PACTI estimates that 2800 projects will be supported by Pappe Subvenção during 2008 and 2010

The most important funding programmes are (see de Morais 2008: 73):

- *Credit lines*: Programa Pró-Inovação – grants funding for RD&I projects for medium and large enterprises, with subsidized interest rates, Programa Juro Zero – grants interest free funding for micro and small enterprises,
- *Non-reimbursable resources*: benefits universities, educational institutions, incubators, parques tecnológicos and SMEs in research and innovation projects, support for researchers and installation of research infrastructure,
- *Economic subsidies*: grants resources directly to enterprises for the cost of R&D following the Lei de Inovação, grants for researchers: supports companies in covering part of salary for researchers, PhDs, or employees in innovation activities, following the Lei do Bem),

- *Venture capital*: support for innovative enterprises through the acquisition of quotas of investment funds (venture capital funds, start-up capital and private equity) and incentives for the participation of corporate investors in technology-based enterprises, support for the interaction of investors and entrepreneurs.

Compared to the ERA-Net scheme, The FNDCT and FINEP as its managing organization act as umbrella for various funding sources. Coordination takes places with ministries as well as with subnational units. The partners are committing funds to a common pot. It is a horizontal support scheme that is primarily geared towards private sector support but also aims at supporting common research needs. The FNDCT is Brazil's central funding pot which guarantees a stable flow of resources.

Evaluation and impact: Table 3 shows the various funding sources for FINEP`s programmes and that between 2005 and 2007 FINEP allocated resources totalling R$ 2645.3 million (884.72 million €) to 1162 companies. The overwhelming majority (R$ 1653 million, 552.9 million €) was spent in the program "Pró-Inovação" that is aimed at financing expenditure for innovation in medium and large companies. 142 companies were supported leading with an average of some R$ 11.6 million (3.88 million €) per company. What is startling, however, is the minuscule support for SMEs. The Programs "Juro Zero" and "Pappe Subvenção" that both focus on SME totalled only to R$ 271.1 million (90.6 million €) - including the resources from sub-national governments. Considering the sheer number of SMEs in Brazil, the amounts devoted to this segment of the private sector is very small.

3.3.2.2 The Sectoral Funds for S&T (Fundos Setoriais para Ciência e Tecnologia)

Relatively new, but very important institutions in Brazil are the so-called Sectoral Funds for S&T (Fundos Setoriais para Ciência e Tecnologia, FS) that were implemented from 1999 onwards. Their goal is to overcome the structurally lacking connections between public and private R&D activities by guaranteeing long-term and stable financing. This mechanism, which is one of the most influential instruments in Brazilian ST&I policy, reflects the rather traditional pattern of sectoral promotion. It aimed to overcome the low investments of the private sector in R&D by providing stable financing. Resources come from a complicated re-direction of certain percentages of existing and new taxes and levies on sectors' services and operations which are collected in the FNDCT. FINEP is the executing organization for each Sectoral Fund.

Currently, there are 16 funds operating, 14 sector-specific and two horizontal funds (Fundo Verde Amarelo, CT-Infra). The latter are oriented towards building up research infrastructure and mechanisms to support university-industry research relations. The Fundo Verde Amarelo and CT-Infra aim at extending cooperative research processes through the whole innovation process and not just for supporting isolated research projects.[37]

Each FS has a different revenue formula and can only finance research of interest to the respective sector (see Table 4). The governance of each FS is based on the participation of various private actors and aims at establishing and achieving long-term strategic goals. So-called *comitês gestores*, sector specific public-private commissions, are responsible for setting research priorities. In order to have a legal common framework, the National Fund for Scientific and Technological

[37] Oil and Gas - CT-Petro; Energy - CT-Energ; Water Resources - CT-Hidro; Transportation - CT-Transporte; Mineral Resources - CT-Mineral; Spatial Activities - CT-Espacial; Informatics - CT –Info; Agribusiness - CT-Agro; Biotechnology - CT-Biotec; Health - CT-Saúde; Aeronautics Sector - CT-Aeronáutico (Setor Aeronáutico); Development of R&D Activities in the Amazon region - CT-Amazônia; Marine and River Transportation and Naval Construction - CT-Aquaviário; Telecommunications – Funttel; Green-Yellow Fund – FVA; Infrastructure – CT-Infra

Development (FNDCT) was reactivated. While resources in the initial years of its implementation were scarce due to serious internal and external economic turmoil[38,] the fund's investments began to rise.

Fundo	Origin of resources
CT-Petro	25 % of royalties that exceed 5 % of oil and gas production
CT-Info	At least 0,5 % of gross revenue of companies benefitted by the Lei da Informática
CT-Infra	20 % of resources of every fund
CT-Energia	Between 0,75 % and 1 % of revenues from concessionaries
CT-Mineral	2 % of financial compensation (Cfem) paid by companies with mining rights
CT-Hidro	4 % of financial compensation collected by electric energy producer
CT-Espacial	25 % of revenue for utilizing orbital positions; total revenue of licenses and authorizations of the Brazilian Space Agency
CT-Saúde	17,5 % of Cide (1)
CT-Biotec	7,5 % of Cide
CT-Agro	17,5 % of Cide
CT-Aero	7,55 of Cide
Fundo Verde Amarelo	50 % of Cide, 43 % of IPI (2) revenue for products that benefitted form the Lei da Informática
CT-Transp	10 % of revenue of the National Department of Transport Infrastructure (contracts for utilizing terrestrial infrastructure)
CT-Amazonia	At least 0,5 % of gross revenue of informatics companies in the Zona Franca de Manaus

Table 4: Origins of the resources of the FS

Source: de Morais (2008: 75)

(1) Contribution for the intervention of economic domain over the import and comercialization of oil and its derivates, natural gas and its derivates as well as biofuels (Contribuicao de Intervenção no Domínio Economico incidente sobre a importação e a comercialização de petróleo e seus derivados, gás natural e seus derivados, a álcool etílico combustivel (Cide))

(2) Industrialized product tax (Imposto sobre Produtos Industrializados, IPI)

Through the implementation of the FS a highly vertical incentive structure was adopted, that privileged sector-specific research. *Compared to the ERA-Net scheme,* the rationales of the FS scheme are well comparable to those of ERA, i.e. addressing issues of **competitiveness and societal challenges.** One of the fundamental goals of the FS is to created stable funding for long-lasting networks of research institutions and the private sectors. Though this has not always been achieved and in spite of their shortcomings, the Sectoral Funds (and the FNDCT as overall structure) have become the most important support programmes for the creation of critical mass in terms of social-technological challenges and securing competencies.

Evaluation and Impact: By 2006 more than 1.2 billion R$ (ca. 400 million €) were allocated to S&T programs (see Figure 3). Sector relevant research may obtain non-reimbursable funding (recursos não reembolsáveis) when developing new knowledge in areas considered important by the sector commission. Since their creation in 1999, approximately R$ 2.3 billion (ca. 765 million €) were distributed to universities and public research institutes to finance research projects independently of private sector participation (de Negri et al. 2008).

[38] In 1999 Brazil suffered a severe economic and fiscal crisis that resulted in a devaluation of the Real by roughly 30%.

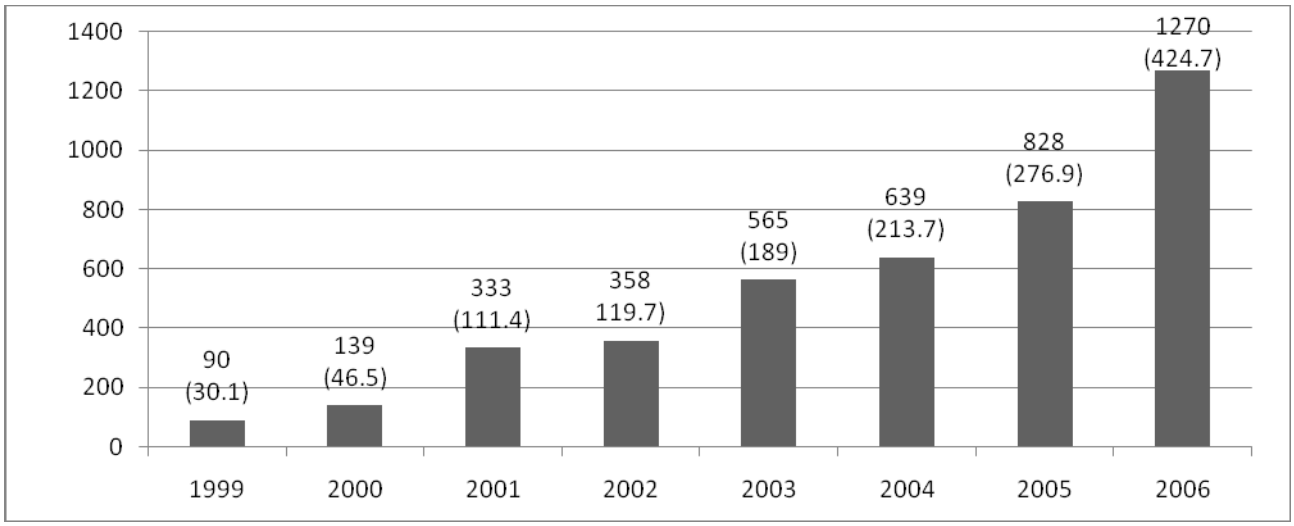


Figure 3: Financial execution of the Fundos Setoriais in million R$ (and €)

Source: Salerno and Kubota (2008: 33)

The creation of the FS opened up new opportunities for private sector investments in S&T. Cooperative projects (public research together with private companies) are, however, responsible for no more than 20 % of total reimbursements of the FNDCT (de Negri et al. 2008: 298). For those companies that participated the overall impact of the FNDCT was significantly positive for participating enterprises in terms of technological outcomes such as new patents (de Negri et al. 2008: 317). The rest was allocated in other forms of cooperative agreements since not only private enterprises are eligible, but also NGOs, foundations, public organs and even ministries. Also, since the program proved to be rather limited, the FNDCT did not contribute extensively to long-term network-creation

3.3.2.3 Life Science Biotechnology Competitiveness Programme

The aim of the programme is to strengthen the management and planning of government activities in the areas of biotechnology, more specifically to encourage technological development and innovation in strategic sectors of application of biotechnology, such as agriculture, human and animal health, environment and industry, in line with the national policy of biotechnology. The Biotech Programme was introduced in 2007. Biotechnology is seen as one of the major growth markets worldwide and Brazil disposes of the world's most diversified flora and fauna. Also the agribusiness as one of the most important national economic sectors can derive advantages of Biotechnology is interested in further research activities.

According to PACTI there are roughly 1700 research groups across the country with some scientific activity and with potential to develop products with the private sector. These research groups are the target groups. Biotechnological applications should be promoted, since the lower costs of production and increasing investments, especially venture capital, constitute a promising scenario for industry. In the case of biotechnology, the generation of specific products and processes involve high-risk, long maturation and large volume of investments, requiring appropriate government action to attract the necessary public and private investment. In order to do that the planned activities include: fiscal and tax incentives, support research infrastructures, human capital formation, establish cooperation with state and municipal technology centres, establish regulations and standards for bio safety and IPR.

Compared to the ERA-Net scheme, the Brazilian Biotech Programme resembles the thematic coordination around a specific topic. Funding comes from federal as well as subnational sources, involving departments and agencies with Biotech R&D budgets. According to the information available, it seems that Biotech Programme coordinates a large share of the available resources of the participating institutions for this sector, while in ERA-Nets the partners can commit a certain share of their funding. The partners include all the major ministries MS, MDIC, MAPA, MMA and the MCT as well as the most influential research organizations CGEE and FIOCRUZ, as well as Associações empresariais, CIEGB, SECyT from Argentina. The level of the calls remains largely national. There is, however, a capacity building module that supports the training of students with Argentina.

Evaluation and impact: The outcome of the Programme as of 2010 includes:

- Cooperative projects under the call "Economic Subsidy", which already resulted in the development of 69 products, involving 65 companies with an investment of R$ 137.6 million,
- Also 49 pre-clinical and clinical basic research projects have been supported regarding the development of innovative therapeutic procedures in cell therapy, totalling $ 10 million (2008-2009) through CNPq calls, thus contributing to the goal of strengthening centres of excellence in preclinical testing and bioassays in different regions,
- The creation of the national network of Cellular Therapy was support (eight centres for Cell Technology located in five Brazilian States made of 52 laboratories).

The programme "Competitiveness in Biotechnology" achieved the following:

- Creation and expansion of the integrated network of Genomic and Proteomic Studies (Genoprot), with funding of 63 research projects and 20 curses in basic proteomics technology that resulted in training of about 230 people throughout Brazil,
- Support the activities of Brazilian-Argentine Center of Biotechnology (CBAB), with funding 133 courses for more than 1,730 students, and 29 research projects carried out by Brazilian and Argentinean research groups,
- Creation and expansion of Renorbio, with 509 projects financing research and PhD Fellows 425 with FNDCT features and other sources, which resulted in the granting of 11 titles Doctor until 2010.

support for 3 Brazilian Genome Network project, 9 Regional Networks of Genomes, formation and consolidation of the national laboratory of Structural Molecular Biology, 74 research projects resulting from 4 public calls, and 11 research projects contracted through open calls.

Table 5 summarizes the resources made available within Brazil's Biotechnology Competitiveness Programme and shows the share of participation of each institution.

Recursos (R$ milhões)					
Origem	2007	2008	2009	2010	Total
MCT/FNDCT*	31,00	37,20	44,60	53,60	**166,40**
MCT/outras ações PPA	5,48	6,00	5,81	6,10	**23,39**
Contrapartida**	4,00	4,00	4,00	4,00	**16,00**
Total	**40,48**	**47,20**	**54,41**	**63,70**	**205,79**

** Recursos dos Fundos de Biotecnologia, Saúde e Agronegócios, excluindo–se os investimentos necessários para biocombustíveis; recursos de bolsas contabilizados no programa 2.1 (Formação de Recursos Humanos para C,T&I); e recursos para cooperação internacional contabilizados no programa 1.2 (Cooperação Internacional).*
*** Contrapartida das Fundações de Amparo à Pesquisa dos Estados envolvidos no GENOPROT.*

Table 5: Resources of Brazil's Biotechnology Competitiveness Programme

3.3.2.4 Specific coordination actions with the subnational level

It has been outlined so far that the federal level comprises various programs and ultimately the vast majority of funds which leads to an accentuated position of the national level in the support of the innovation process. However, in recent years, the MCT has actively tried to establish a more profound relationship with subnational units. By establishing the National Council of State Secretaries for Science and Technology (Conselho Nacional de Secretários de C&T, CONSECTI) and the National Council for State Foundations for Research Support (Conselho Nacional de Fundações de Amparo à Pesquisa, CONFAP) there is a direct formal channel to exchange information and suggestions by subnational units to the national level and vice versa.

According to official information (see for the following MCT 2007: 51), there were various partnership agreements between the MCT and subnational units during the time span between 2003 and 2006. The most important include the following:

- Programa de Desenvolvimento Científico Regional (Program for scientific regional development). The goal of this program was to support projects related to regional research institutions in need of qualified researchers. The CNPq would grant a scholarship to researchers, while the respective institution would pay for the research project. During 2003 and 2006, 519 agreements worth R$ 84 million (28.09 million €) were signed.
- Open calls for financial support of research and technological development projects. This measure was administered by FINEP (see above) and benefited projects that helped to (re-) structure regional ST&I systems. The states' counterpart was defined through criteria proposed by CONSECTI and CONFAP. Accordingly, states with higher GDP have to account for a larger counterpart than poorer states, whose proportion is somewhat less. Within two years, the calls distributed R$ 30.5 million (10.2 million €) (R$ 15.5 million in 2005 and R$ 15 million in 2006) in non-reimbursable funds derived from the FS.

There are also important arenas for negotiation between federal and state level, as for example the CONSECTI that was created in 1987 to integrate subnational ST&I efforts. In this forum, state secretaries would meet periodically in order to coordinate a common position vis-à-vis the federal level. In 2005, due to the realization of a need for more systemic action, the Forum became formalized on the national level and changed its name to Conselho Nacional de Secretários para

Assuntos de CT&I (CONSECTI). The Research foundations followed the same course by founding the Conselho Nacional das Fundações Estaduais de Amparo à Pesquisa (CONFAP).
Today, these councils serve as a communication channel between subnational and federal entities and as a place for exchanging ideas, information and experiences in ST&I policy-making. The creation of forums to represent subnational interests on the national level can also be seen "[…] as a way of overcoming the historic lack of tradition of the state governments in Brazil in the promotion and support of scientific and technological development." (Gusmao/Ramos 2006: 4)
Evaluation and impact: The CONSECTI has only limited political power and its visibility is rather limited (Stehnken 2010). As the CONSECTI plays no major role in the political power game, it seeks informal ways to voice its opinion. It aims at establishing direct interactions between representatives of CONSECTI and certain members of the federal bureaucracy, e.g. influential actors within MCT. Being well aware of that situation, states are pressuring for differentiated treatment. Successful cases of pressuring involve, for example, that federal calls of projects nowadays include a regional dimension.

3.3.2.5 S&T for socio economic development

The PACTI 2007-2010 is very explicit regarding the use of modern technologies to contribute to the vast social needs of large segments of the society. In Brazil, the keyword of the discussion is "digital inclusion" which refers to the urgent need to enable those groups that are not yet included in the so called knowledge society. The PACTI considers to widen the base in society for creating and using scientific and technological knowledge by increasing the access to information and the efforts for qualification by implementing telecentres, Vocational Technological Centres (Centros Vocacionais Tecnológicos - CVTs) and technology extension programmes. In terms of resources, special priority is given to the least-favoured regions in Brazil. The implementation of the various programmes that support the "digital inclusion" are managed by federal as well as subnational institutions. Also, part of the effort refers to strengthen inter-regional cooperation and exchanges between regional institutions mainly regarding policy learning.
This programme line of PACTI is supported by resources coming from the MEC, State and Municipal Secretariates for S&T, Universities, CNPq, business associations, cooperatives, public and private banks such as the BNDES, the Caixa Econômica Federal and Banco do Brasil and public and private research institutes.
Compared to the ERA-Net scheme, this programme line in Brazil is interesting regarding its mission orientation and the implications for policy coordination. Digital inclusion and the spreading of S&T in society is not necessarily frontier research, but Brazil managed to join several distinct actors around this mission and to raise the awareness for the special needs of poorer regions.
Evaluation and impact: Regarding technologies for social development the MCT funded 471 projects for Vocational Technological Centres between 2003 and 2009. The total investment for this programme was R$ 284,9 million (roughly € 100 million).

4 Russia

4.1 Introduction

4.1.1 Economic and political trends

According to the OECD data, the Russian Federation with 141 million inhabitants has less than 1/3 of the population of the EU27 Countries (500 million). In 2006, the Russian GDP became the seventh in the world and had a growth of 50 % from 2002 to 2006. The GDP per capita was about 16,300 US$ in 2008 in comparison to about 30,000 US$ for the EU27. On the development perspective, Russian Federation surpasses the EU27 countries in terms of the GDP growth rate. In 2008, the GDP of the Russian Federation annually grew by 5.6 %, while in Europe it remained at 0.8 %. GDP growth and employment trends (7.1 % for EU27 and 6.5 % for the Russian Federation) look better than corresponding indicators of average economic performance for the EU27 (Ivanova et al. (2007).

Population (Head count, 2008)	141.4 mill.
GDP per capita (in US$, 2008)	16,300 (est.)
GDP growth rate (2008)	5.62 %
Unemployment (2008)	6.5 %
R & D intensity (GERD/GDP, 2008)	1.03 %
Share of private sector R&D (2008)	28.7 %
Share of public sector R&D (2008)	64.7 %
Innovation Performance (innovation gap 2008 compared to EU-27)	-31 %

Table 6: Indicators for Russian Federation at a glance

Sources: OECD (2010) country profiles, CIA World Factbok, Eurostat, European Innovation Scoreboard (EIS) 2009

The indicator on Innovation Performance provided by the European Innovation Scoreboard indicates that Europe exceeds the Russian performance by 31 %.

According to the INNO-Policy TrendChart, *"the level of gross domestic expenditure on R&D in the 1990s has dramatically decreased in comparison with Soviet times. At the start of the 21st century, despite steady economic growth and improvement in the macroeconomic indices for the Russian economy, R&D and innovation expenditures have increased so slowly that there has been no real growth in the national R&D/GDP ratio (although 2006 is expected to be the first year of progress). In 2008 it was 1.03 %"*.

The share of private sector in support of research and development is very low (28.7 % in 2009) and does not seem to increase as the budget for research and development.[39] The main structural feature of Russia is the dominating share of the government funding. The share of the public sector in R&D was more than 70 %.

From a more general viewpoint, Russia's economic structure is different from that of most European countries due to its predominance of large companies and concentration on specific traditional sectors.

[39] Between 2003 and 2007 budget for the civil science grew by 10-15% a year in real terms, while private intramural expenditure on R&D as % to GDP has grown from 0.95 % in 1998 to 1.07 % in 2006 (Ministry of Education and Science of the Russian Federation 2009).

The INNO-Policy TrendChart (Ivanova et al. (2007) reports that, "*Most Russian businesses have no clear innovation strategy and are not used to investing in their R&D capacity. The R&D system is still quite isolated from market and society demands. It badly needs to improve its performance and level of integration with business and civil society. This situation represents one of the reasons why there have been low levels of innovation activity and technological progress.*"

4.1.2 Overview on Russia's national innovation system

The Concept of Long-Term Socio-Economic Development of the Russian Federation for the Period Till 2020 (CLTD 2020)[40] was adopted in November 2008. It states that the transition of the Russian economics to innovation development is impossible without the formation of a globally competitive National Innovation System (NIS)[41]. The set up of legal, financial and social institutions would ensure interaction of the education, science, business enterprise and non-profit organizations in all spheres of economics and public life.

The Russian innovation system is characterized by a strong public/state dimension of the intermediaries, the industrial system and of the research and education system.

The Research and Education System in Russia is strongly supported by the **Political System** and by the related institutions for **the Administration**. **President of the Russian Federation** has as a reference in these topics, the Council for Science, Technologies and Education that constitutes a permanent set of appointed persons – primarily Russian scientists – for advising and consultancy, **Federal Government and the Prime Minister** established the High Technologies and Innovations Governmental Commission for the coordination and cooperation of all state institutions and scientific bodies for elaboration and implementation of the national innovative system, economic development based on science, nano-technological industry, long-term forecasting.

In addition, public executive bodies responsible for science and technology and innovation policy are essentially:

- The **Ministry of Education and Science**, which occupies a central place in forming and implementing public research and innovation policy and operates concretely through two agencies (the Federal Agency for Science and Innovation - FASI or Rosnauka - and the Federal Agency for Education - Rosobrazovanie),
- Other ministries involved in policy making and coordinating activities related to this area such as the **Ministry of Finance**, the **Ministry of Economic Development**, the **Ministry of Industry and Trade**, the **Ministry of Energy,** the **Ministry of Defence**[42] and the **Federal Space Agency**,
- Some governing (controlling) authorities such as the **Federal Service for Intellectual Property, Patents and Trademarks** (Rospatent), the **Federal Agency for Technical Regulation and Metrology** and the **Federal Antimonopoly Service (FAS)**. **The Research and Education organizations** (also those devoted to the transfer of technology and to the promotion of innovation) are essentially funded by the Russian Government through the Ministry of Education and Science.

[40] Approved by the Resolution of the Government of the Russian Federation No. 1662-r of 17 November 2008.

[41] The National Innovation System (NIS) approach Kuhlmann and Arnold (2001) offers a heuristic approach to describe and illustrate the main aspects of research, technology, development and innovation and its political and economic framework. In this representation, four major groups of actors define a NIS: the Political and Administration System, the Research and Education System, the Industrial System and the Intermediaries.

The graphical illustration tries to summarize the National Innovation System of the Russian Federation. The grey area between the blocks represents the importance of the public/political/administrative sectors in all the three other areas (the Research and Education System, the Industrial System and the Intermediaries).

[42] The Ministry of defence devotes a consistent part of its budget for research.

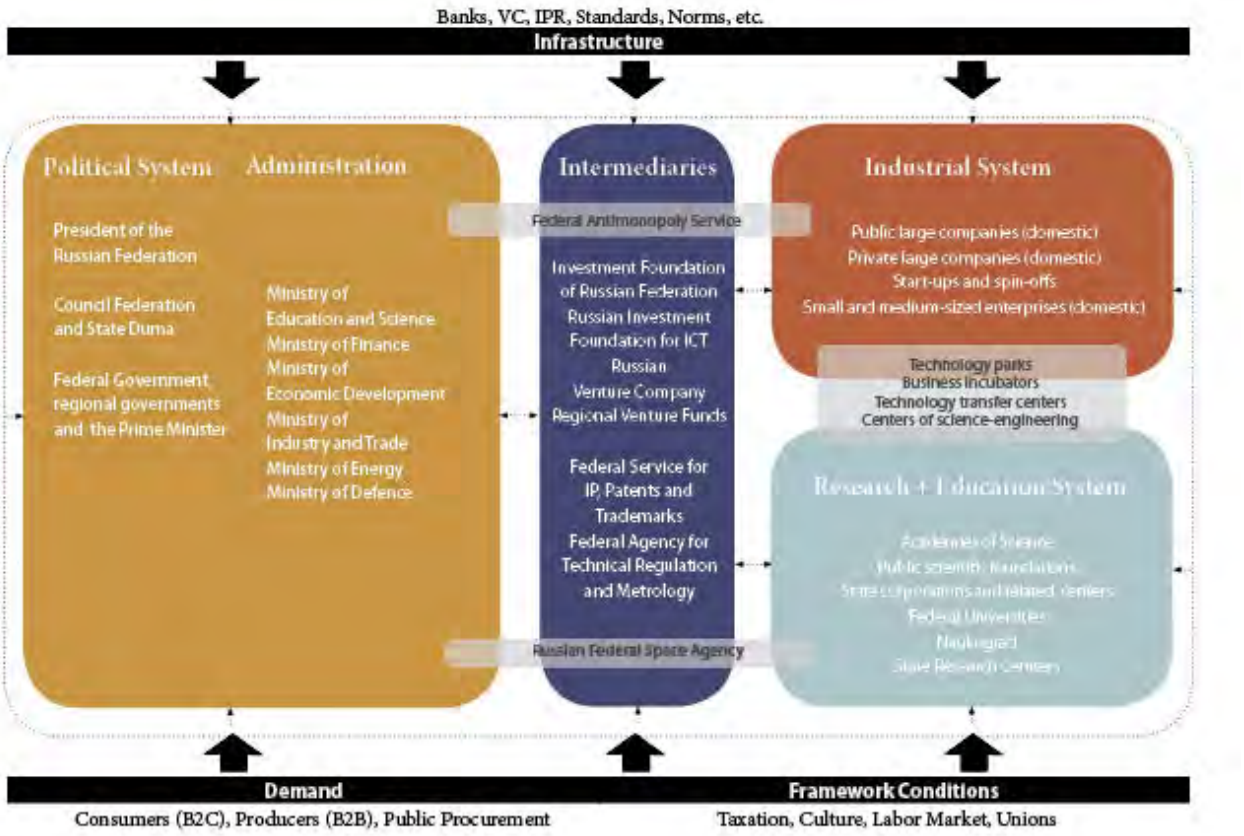


Figure 4: Russia's Innovation System at a glance

Source: Own compilation

The main actors of the **Research and Education System**, overwhelmingly belong to the public sector:

- **6 State Academies of Science**: in detail the Russian Academy of Sciences and by thematic area the Russian Academy of Medical Sciences, the Russian Academy of Education, the Russian Academy of Agricultural Sciences, the **Russian Academy of Architecture and Construction Sciences,** the **Russian Academy of Arts.** All these academies have scientific research institutes, related territorial branches and auxiliary scientific and social units (about 850 organizations),
- Also to be mentioned is the Russian Academy of Natural Sciences as a non-governmental organization – association of scientists and institutions, accredited by the Ministry of Industry and Technologies,
- **2 main public scientific foundations**: in detail, the Russian Foundation for Basic Research (RBR) funds scientists undertaking research on their own initiative, supports the creation of computer and information resources, , for disseminating science and for supporting the scientific community; and the Russian Scientific Foundation for the Humanities (RFHR)[43],

[43] Both foundations aim at funding on a competitive basis the implementation of small projects of fundamental research. The budget for RFBR and RFRH is a fixed share of the total federal expenditure on the civil science.

- **The state corporations, related research/experiment centres** (focus on basic research and/or applied research), **start-ups and spin-offs**. In particular, at the beginning of nineties, a small part of the large industrial research institutes were awarded the status of Public Science Centers (PSC), in order to maintain the scientific potential and unique research equipment,
- **About 70 naukograd** ("science cities"), are towns that have concentrations of scientific research and production, and specifically, towns that have been recognized for their scientific capabilities and hence get special funding privileges[44],
- The so-called **Federal Universities** (regional unions of universities, with strong research and education potential) and the **State Research Centers** (with their official association www.agnc.ru) and among these the Keldysh Research Center (www.kerc.msk.ru), the Orion Research and Production Association (www.orion-ir.ru), the Russian Center of Science "Applied Chemistry" (www.rscac.spb.ru).

In addition from the financial viewpoint, there are separate governmental funds for special innovative projects and scientific programs provided by Skolkovo scientific centre "Kurchatov Institute" for nano-, bio-, informational and cognitive technologies (www.kiae.ru). There are also annual one-time individual and collective grants of the Russian Federation President and other financial resources, mainly devoted to applied research. Others, are provided by the National centres of development (such as Rusnano - www.rusnano.com), by the Vnesheconombank (www.veb.ru), the Russian venture company (www.rusventure.ru).

The financial infrastructure devoted to research and innovation is one of the critical points in the Russian Federation. The main contributors are the Investment Foundation of the Russian Federation, the Russian Investment Foundation for Information and Communication Technologies, the Russian Venture Company and the regional Venture Funds.

In Russia, the R&D activity is financed not only from the public budget, but also by the business enterprise sector and foreign organizations. According to the report of the National Innovation System in Russia (Ministry of Education and Science of the Russian Federation 2009), a rather recent tendency revealed that in the last years there was a growth of expenditure on R&D by large business: *"Companies either create their own research divisions or institutes, including by purchase of the former departmental research institutions, or increase expenses on research projects implemented by organizations of the government sector of science and higher education institutions"*. Rosstat (www.infostat.ru/catalog.html) provides data on R&D financing for OJSC (Open Joint Stock Company) "Gazprom", RAO "EES of Russia" and OJSC "LUKOIL": in 2006 they invested 1.6 % of the intramural expenditure on research and development into R&D or 5.7 % of the total expenditure on R&D in the business enterprise sector.

As a consequence, the **Industrial System** (including the public industrial sector) has to be considered both as one of the creators of new knowledge through R&D in the corporate sector and the subject of demand for research results. According to Rosstat, out of all organizations which implemented technological innovations, 29.6 % were engaged in the research and development industry. In 2007, they increased to 33.5 %. In the period between 1999 and 2006, the absolute expenditure of companies on technological innovations has nearly doubled.

[44] About thirty naukograd are located in Moscow Region and the rest mainly in the Volga, Urals and Siberian regions. Some are now "closed" as there are some towns where Russia's nuclear military work is still not carried out. Some have military connections, like Fryazino that develops advanced radio and electronics devices, but most are now focusing on civil work also exploiting Western aid funds. Among the most famous, there are those operated by the Russian Academy of Sciences, for example Pushchino, a center for biological sciences, and Chernogolovka, a center for physics and chemistry.

Although, the absolute low level and low intensity of expenditure on R&D, remain the key characteristic of the Russian industry. All organizations investigated by Rosstat spend approximately three times less on R&D (38.6 bill Rbls. in 2007 by 830 companies) than the leader of the European science-intensive companies.

It is important to stress that the most relevant Russian business companies are linked to the traditional sectors (oil, gas, metals and other mineral resources[45]) that are usually characterized by low innovation activity with restricted demand for R&D. Nevertheless, getting large profits from the advantages of their market positions they can access the most advanced technologies available on the global market.

Among the other **intermediaries** operating in Russia, there are more than 80 technoparks and still more innovation technological centres, over 100 technology transfer centres, 10 national innovation analytical centres, 86 centres of science-engineering information, about 120 business incubators, and 15 innovation consulting centres.

4.2 Overview on Russian research and innovation policies

4.2.1 Organization and main instruments

This section gives a general introduction into the policy-making of Research, Technology, Development and Innovation policies and programmes. This section also introduces the organisation between the federal levels and the main instruments of RTDI policy. The specific issues of the coordination of sub-national policies is being dealt with in section 4.3.

Several recent official policy documents confirm the innovation target of the government of the Russian Federation. In particular, *"The Annual Message of the President to the Federal Meeting"*, stresses the importance of scientific and research outcomes in order to build conditions for competing at the global level. The midterm strategy is *"the formation of a balanced sector of R&D and effective innovation system providing for technology modernization of economy and competitiveness on the basis of modern technologies and the transformation of science potential into one of the main resources of sustainable economic growth" (Ivanova et al. (2007))*.

The Russian policy system is essentially centralized in terms of budget and determined predominantly by the Federal Government. The Ministry of Education and Science is the main player of the Political and Administration system within the research and innovation context.

The operative arms of the Russian Ministry of Education and Science are:

- The Federal Agency for Science and Innovation (FASI or Rosnauka), established in 2004, which distributes the national budget, implementing programmes for R&D projects, providing research grants and supporting leading scientific groups,
- The Federal Agency for Education (Rosobrazovanie) was established in 2004, provides support for education and manages some programmes for universities,
- The Foundation for Assistance to Small Innovative Enterprises (FASIE), established in 1994, funds programmes for applied and market oriented research with the aim of developing innovative and technology oriented enterprises and start-ups.

Strictly linked to the Ministry of Education and Science are also the public foundations.

The Federal law *"On Science and State Scientific and Technological Policy*" in 1996 represents the first document defining a formal innovation strategy for the Russian Federation. After 2000,

[45] 14 out of 20 top Russian companies in 2004 and already 18 out of 20 in 2008, according to the Rating Agency "Expert-400".

several consequent conceptual documents for specifying the strategic, long-term research and innovation policy have been defined.

The Federal law "*On Science and State Scientific and Technological Policy*" (redrafted in 2006), defines the main objectives of the state scientific and technological policy. The main components of the innovation policy were identified in: the acknowledgment of science as a socially significant branch, the selection of priority directions of science and technology development, the priority of basic scientific research, the integration of science and education in R&D, the competition and entrepreneurial business in science and technology, the concentration of resources in priority areas, the promotion of scientific, technological and innovation activity, the creation of public research centres and other structures (Ministry of Education and Science of the Russian Federation 2009).

Long-term objectives of the Russian Federation in the field of science, technologies and innovations starts with a number of policy documents adopted in 2002 − 2007:

- Fundamentals of the RF Policy in the Sphere of Development of Science and Technology for the Period of up to 2010 and beyond in 2002,
- Principal Directions of the RF Policy in the Sphere of Development of Innovation System for the Period of up to 2010 in 2005.

The following relevant documents are the *Strategy for the Development of Science and Innovation in the Russian Federation up to the year 2015. They were* defined by the Ministry of Education and Science in 2006[46] and *the Integrated Programme for the Scientific-Technological Development and Technological Modernisation of the Economy of the Russian Federation up to the year 2015*[47], which were published in 2007.

In addition, the *Concept of Long-Term Social and Economic Development of the Russian Federation Until 2020* (CLTD 2020) was adopted in November 2008. CLTD 2020 was defined as the key objective for the transition from the export-raw material economy to the innovation model of economy capable to improve competitiveness of the Russian products and services on the domestic and world markets (Ivanova et al. (2007)). For the improvement of the national competitiveness, the need for the evolution of the economic system from the traditional consolidated sectors to new research- and innovation-based areas, the essential conditions are; a growing demand of innovations from industries, a growing efficiency in terms of knowledge generation and supporting infrastructures and policies (Ministry of Education and Science of the Russian Federation 2009).

For this goal, the key targets of CLTD 2020 described in the *National Innovation System and State Innovation Policy of the Russian Federation* are:

- The share of organizations implementing technological innovations should grow to 15 % in 2010 and to 40-50 % in 2020 (10 % in 2007),
- The share of Russian high technology products and services on the world market should reach 5-10 % by 2020 in at least 5-7 economic sectors, including nuclear power generation, aerospace equipment and services, special shipbuilding, some niches on the software market,

[46] The medium-term objective of the Strategy is formulated as follows: *"... the formation of a balanced R&D-effective innovation system sector, providing the technological modernization of the economy and enhancing its competitiveness through advanced technologies and transformation of scientific potential in one of the major resources for sustainable economic growth."*

[47] http://mon.gov.ru/work/nti/dok/.

- The percentage of exportation of Russian high technology products in the world should grow to 2 % by 2020 (0.3 % in 2007),
- The specific share of innovation products in regard to the total industrial products should grow to 6-7 % in 2010 and to 25-35 % in 2020 (5.5 % in 2007),
- The intramural expenditure on research and development should reach 2.5-3.0 % by 2020 (1.1 % in 2007). More than the half should be in the private sector.

Additional provisions to CLTD 2020 are defined in the document *Long-Term Forecast of Science and Technology Development in the Russian Federation Till 2025,* which outlines the strong and weak aspects of Russian R&D and its elements. The preparatory work, organized by the Ministry of Education and Science, in conjunction with other federal departments and the Russian Academy of Sciences, concludes that the transition to an innovative scenario of country development lies in the fact that Russia should recover the gap in the level of technological development of the economy and create conditions for a higher growth in sectors of its future specialization in the global economy.

More recently, a plan of the measures for the stimulation of innovative activity of enterprises to be carried out in 2009-2010, has been elaborated within the governmental actions for R&D. *"The plan includes measures for support of the priority areas of technological development, innovation activity of established businesses for improvement of the institutional environment, for support of the establishment of innovative business and upgrading efficiency the innovation infrastructure, creating incentives for innovation activity in the public sector." (Ministry of Education and Science of the Russian Federation 2009)*

Instruments and measures for stimulating innovation have also been created with a sectoral perspective such as: the *Energy Strategy of Russia for the period up to 2020*, the *Federal Space Program*, the *Development of Technologies for Civil Aviation*, the *National Engineering Capability*, the *Strategy of Development of Russian Chemical and Petrochemical Industries for the Period of up to 2015*.

Looking at the tools for implementing R&D measures, diversified approaches have been adopted: foundations operate through competitive funding schemes, Federal Targeted Programmes use public-private co-funding and central government introduce tax breaks.[48]

4.2.2 Main objectives and major trends

Russian innovation objectives and their trends are formulated in several official concepts and stressed in *The 2006 Annual Message of the President to the Federal Meeting* stating that, *"under conditions of international competition the country's economic development mainly depends on scientific and technical achievements"*[49] and particular attention should be posed to new knowledge creation, to import new technologies, to protect intellectual property rights and to encourage investments in innovations.

The Main Directions of the Russian Federation Policy in the Development of NIS by the year 2010[50] designs a National Innovation System according to international practice improving:

[48] Among the suggested measures: tax exemptions on VAT for income related to selling patents or licenses on innovative technologies; tax exemptions on profit from income received by R&D organizations and foundations supporting science and education; inclusion of expenditures on R&D in the prime cost of products; widening the list of expenditures for which a administratively simplified scheme for paying taxes may be used; increasing financial contributions to the Russian Fund for Technological Development.

[49] "The Message of the President Vladimir Putin on the 10th May 2006.

[50] This document was approved by the Prime Minister on the 5th August 2005.

- Knowledge creating capacities, including basic research in Russian Academy of Science, other public Academies and universities,
- Applied research and development in government and industrial research centres,
- Production of competitive innovative industrial and agricultural goods,
- The innovation infrastructure,
- Training of innovation management personnel.

Also from the innovation policy instruments side, a more comprehensive policy mix is developing. Up to 5 years ago, the focus of government policy shifted from the direct support of innovation in the terms of the financing of innovation infrastructure, grants to small high tech companies, financing of training and retraining of personnel to indirect effective measures and administrative (legal) regulations, which are although at a preliminary stage. They include essentially sector specific measures: large innovation projects important to the government; creation of a Venture Fund; and creation of special economic zones.

In addition, budgetary expenditures on R&D continues to grow (in 2006 the annual growth rate reached the 17,9 % in real terms). 87 % of total expenditures on R&D are distributed in four programmes:

1.) Federal Space Program,
2.) Development of Civil Aviation Technology,
3.) R&D in Priority Directions of Development of Science-Technological Complex of Russia,
4.) National Technological Basis.

For these programs the latest annual rates of growth were the following: 100 % - for Development of Civil Aviation, 60 % - for Technological Basis, 17 % - for Space Program, and about 10 % - for R&D on Priority Directions (Ivanova et al. (2007)).

Despite this increase of available funds, R&D work is mainly allocated to government-owned research organizations and universities[51]. Incentives for the private R&D are currently low.

According to the INNO-Policy TrendChart - Policy Trends and Appraisal Report – Russia, three main policy priority directions initiated by the government can be identified: growing attention towards forecasts and foresight procedures; further development of indirect measures to stimulate innovation; and support for innovation infrastructure.

Furthermore, in terms of the fields of science and technology development up to 2010 and beyond, priorities and critical technologies have been identified. A strong thematic focus has been put on nanotechnologies (through the state corporation Rusnano), aerospace, aviation, security and antiterrorism, life sciences, industry of nano-systems and materials, information and telecommunication systems, advanced weapons, military and special technologies, sustainable use of environment, transport, aviation and space systems (for almost the 50 % of the budget allocation), energy and energy saving. In terms of R&D budget in 2007, 4.69 billion Euros or 44 % of GERD, were spent on R&D in these priority areas.

[51] Government allocations on R&D are mainly distributed among the following organizations (in descending order by volume of financing): Russian Academy of Sciences, Russian Agency on Science and Innovations, Russian Academy of Medical Sciences, Siberian Branch of the Russian Academy of Sciences, Russian Foundation for Basic Research (RFBR), Far East Branch of the Russian Academy of Sciences, Russian Agency for Education and Urals Branch of the Russian Academy of Sciences (Ivanova et al. (2007)).

4.3 The Coordination of Research Policies and Programmes in Russia

4.3.1 Introduction to ways and rationales for coordinating and pooling resources

This section shall give a more specific introduction into the way the policies and programmes are organized at the national level, especially in regard to coordinating research. It looks at trends towards centralization at the federal level and whether the notion of Critical Mass appears as a rationale for research policies and programmes at the federal level.

As demonstrated by the description of the main features of the National Innovation System of the Russian Federation, most of the policy decisions such as programmes definitions are centralized. Coordination of different national bodies represents the normal way for doing research in the Russian Federation. In this context, in order to analyze the notion of Critical Mass, scale and scope of research should be considered by sectoral perspective.

As stated above, in 2006 the President Vladimir Putin defined the *Priority areas of development of science, technologies and machines and equipment in the Russian Federation*[52]*:* safety and terrorism prevention, living systems, industry of nanosystems and nanomaterials. information-telecommunication systems, perspective armaments, military and special-purpose machines and equipment, rational nature management, transportation, aviation and space systems, power engineering and energy saving. They are currently representing the technological fields which are concentrated as the largest amount of financial and human resources at national level.

Federal Target Programs (FTP) seem to be the most interesting programmes for coordinated (thematic) research in the Country. Some examples of FTP are: “Development of Nanotechnology Infrastructure in the Russian Federation for 2008−2010”, “World Ocean”, “National Engineering Capability for 2007−2011”, “Development of Electronic Component Base and Radio Electronics for 2008−2015”, “Scientific and Scientific-Pedagogic Cadres of Innovation Russia for 2009−2013”.

On the same and other topics, the Russian Federation is constantly developing effective international cooperation for the R&D sector. Russia is an Associated Countries to the EU's Framework Programme for Research and Development (FP7) and participates to the Technology Platforms, which bring research institutes and companies together, for the Russian case, in Life Sciences and Agriculture.

4.3.2 Selected Initiatives and Programmes

In recent years, the Russian research and development areas experienced a noteworthy growth mainly thanks to institutional incentives. In 2005 10 national information analytical centres (NIAC) were established, within the framework of the Federal Target Research Program *“Research and Development in Priority Areas of Science and Technology Development in Russia for 2002-2006”.* The programme was aimed at monitoring the priority areas in science and technology development, innovation structure of science and engineering activity and regional innovation systems, training the personnel for the research and innovation activity and ensuring their mobility.

In 2006, the Interdepartmental Commission for Science and Innovation Policy, chaired by the Minister of Education and Science adopted the *Comprehensive Programme for the Scientific-Technological Development and Technological Modernisation of the Economy of the Russian*

[52] Approved by Vladimir Putin, President of the Russian Federation on May 21, 2006.

Federation up to the year 2015. The medium-term objective of the programme is formulated as follows: "... the formation of a balanced R&D-effective innovation system sector, providing the technological modernization of the economy and enhancing its competitiveness through advanced technologies and transformation of scientific potential in one of the major resources for sustainable economic growth."

Among the tasks expected to be resolved in the framework of the Strategy, the most important are:

- Creating competitive R&D sector conditions for expanded reproduction,
- Development of an effective national innovation system,
- Establishment of R&D institutes resulting in legal protection,
- Modernization of the economy through technological innovation.

This 2006 initiative laid solid foundations to the actual *Governmental Commission on High Technologies and Innovations,* established in 2007, whose role is to support the 2015 Comprehensive Programme by coordinating research policy. This governmental body illustrates the overall current priority that the Russian top leadership puts on a modernisation of the economy through R&D based innovation. The commission is chaired by 40 representatives issued from many public sector institutions of the Russian research sector which main task is to advice the government on the research policy and related directions to adopt. This Commission and consequently the research incentive policy in Russia benefit from crucial support such as the Minister of Education and Science, Minister for Economic Development, President of the Academy of Sciences, Rector of Moscow State University, head of the Russian Space Agency, as well as heads of research funding bodies.

Research programmes in Russia are therefore mainly publicly founded from the federal budget. The Russian government, in close cooperation with the Commission on High Technologies and Innovations, regularly launched new competitive funding programmes named Federal Targeted Programmes in order to stimulate specific thematic priorities. Among the four sectors covered by the Critical Mass project, the following Programmes in Russia can be mentioned:

- **Industrial Technology and SMEs**
  - Federal Targeted Programme (FTP) on Global Navigation System GLONASS,
  - Federal Space Program 2006-2015,
  - FTP on Nuclear Power and Industry Development 2007-2015,
  - FTP National Technology Base of Russia for 2007-2012,
  - FTP for the Aviation sector 2006-2010 and up to the year 2015,
  - FTP on New Generation Nuclear Energy Technologies for the period of 2010-2020 and with a perspective up to the year 2020,
  - Program of development of nano-industry in Russia till 2015,
  - Federal target program on nanotechnologies 2008-2015,
  - FTP on Research and Development in Priority Fields of the S&T Complex of Russia for 2007-2012,
  - FTP on Nuclear and Radiation Safety Insurance in 2008 and up to 2015,
  - State Foundation for Development of SME's in Scientific-Technological sphere. Programmes developed : *Program "Pusk", Program TEMP – Technologies to Small Enterprises, Program "Razvitie", Program "Umnik", Program "INTER").*

- **Transport**
  - FTP on Modernization of Transport System of Russia for the period 2002-2010,
  - FTP on Development of Transport System in Russia 2010-2015,
  - FTP on Increasing the Safety of Road Traffic in 2006-2012,
  - FTP for the Aviation sector 2006-2010 and up to the year 2015.
- **Environment**
  - Russian Federal Target Program "World Ocean".
- **Life Sciences**
  - FTP on Prevention and Control of Socially Significant Diseases for 2007-2011.
- **OTHERS: ICT**
  - FTP E-Russia on ICT development 2002-2010 + E-government,
  - FTP on Development of the Electronic Component Base and Radio-electronics for 2008 – 2015.

We report information on a selection of such programmes (the ones underlined).

4.3.2.1 Program on Global Navigation System GLONASS

The satellite system GLONASS is intended to provide an unlimited number of nautical, air, space, and ground users with navigation data and precise time signals at any moment and at any point on the Earth and the near-Earth space environment. The orbital constellation of the fully deployed system is composed of 24 GLONASS satellites orbiting in three orbital layers. The main subcontractors are the Russian Scientific-Research Institute of Space Industry (RNII KP) and the Russian Institute of Radio navigation and Time (RIRV). RNII KP is responsible for development of satellite radio equipment; monitoring and control subsystems and receivers for nautical and space users. RIRV deals with development of precise satellite and ground frequency standards, as well as means for their synchronization, and receivers for air and ground users.
The GLONASS Programme is composed of four main elements:

- orbital constellation of GLONASS satellites,
- Ground Control Segment,
- Rocket-space complex,
- Users.

The Federal Dedicated (Mission-Oriented) Program "Global Navigation System" has as its main goals the successful development and effective use of GLONASS, applying advanced SatNav technology to provide State social and economy development and State security, and saving the leading role for Russia in SatNav by guaranteed service provision for Russian and international users.
Program State customers are:

- Russian Aviation and Space Agency (Rosaviakosmos) – Program Coordinator,
- Ministry of Defence of Russian Federation (MoD) – Coordinator of program tasks for Russian Federation defence and security,
- Ministry of Industry, Science, and Technology of the Russian Federation (MoIST),
- Ministry of Transport of the Russian Federation (MoT),

- Russian Agency of Control Systems (RACS),
- Russian Federal Mapping Service (Roskartographia).

In 2009, the head of the Russian Federal Space Agency Anatoly Perminov announced a new GLONASS project called "ERA", an acronym for "Emergency Response to Accidents". This system will provide location services for emergency calls, similar to Enhanced 9-1-1, E112 and eCall. The first phase of the project will include equipping automobiles with GLONASS receivers and creation of back-end software which will provide call centre operators within emergency services with geographic data. The second phase will also involve GPS/GLONASS enabled phones and smartphones. There is also a planned project called "Social GLONASS". It will help people who require supervision, such as old people, children, and people with reduced vision.

Compared to the ERA-Net scheme, the GLONASS project clearly aims at solving a socio-technological challenge as well as a scientific challenge inasmuch as the programme aims to create new knowledge and new research fields in space research. Apparently there is no involvement of subnational actors but a large number of federal ministries are part of the programme which requires extensive coordination.

Evaluation and impact: The total amount of financing: about 2 billion US dollars. It is proposed to launch a further six GLONASS satellites by the end of 2010, after which the GLONASS constellation shall reach its nominal strength of twenty-four satellites, which will make it possible to ensure global, continuous navigation support to GLONASS system users.

4.3.2.2 Program of development of nano-industry in Russia till 2015

Coordinator: Russian Ministry of Education and Science

In the framework of presidential initiative "The strategy of Development of Nanoindustry" introduced in 2007, three main tasks of the nanoindustry development in Russia were set:

- At the first stage, there is a task of cardinal increase of production volume of nanotechnological produce already releasing and selling, saturation of respective markets in the next three-four years,
- The task of the second stage is the development and putting into industrial production of new kinds of nanotechnological produce that are expected at the market in three-five years.

The task of the third stage is the priority development of principally new directions in the sphere of nanotechnologies that ensures the creation of scientific education and medium sized manufacturing in Russia for the next 10-20 years.

The main content of this stage will be development and creation of:

- Produce of nanobiotechnologies,
- Hybrid bionic-type devices and apparatuses,
- Nanobiosystems and devices including principally new hybrid bionic-type sensing systems,
- Biorobotic systems.

Successful solution of the assigned tasks is impossible without appropriate instruments of the national policy in the sphere of nanotechnologies, infrastructure, and effective coordination. For this purpose, the Program of Development of Nanoindustry in the Russian Federation for a period until 2015 and the Federal Target Programme "Development of the infrastructure of nanoindustry in the Russian Federation for 2008-2010" are developed. A significant series of projects related to

nanotechnologies and nanomaterials became a part of the Federal Target Programme "Researches and Developments in the Priority Directions of Development of the Nanotechnological Complex of Russia for 2007-2012". The questions of ensuring interaction of the federal executive authorities in the process of development of nanotechnologies and nanoindustry, formation of the market of nanoproducts and nanoservices are the function of the National Commission for High Technologies and Innovations.

The structure of national nanotechnological network that ensures concentration of resources on the priority directions of researches and development, increase of working efficiency and the level of coordination, creation of favourable conditions for accelerated introduction to the business turnover of new competitive produce of nanotechnologies is forming. The national nanotechnological network already includes and will include in the future:

- The Russian Research Centre Kurchatov Institute that performs scientific activity on realization of the President's initiative "The Strategy of Development of Nanoindustry",
- The Russian Corporation of Nanotechnologies (Rusnano) that solves the problems of organizational and financial support of innovation activity in the sphere of nanotechnologies,
- The organizations that effect financing of the project of nanotechnological development including venture foundations,
- Scientific, educational, design and industrial centres and laboratories established on the basis of universities, Russian Academy of Sciences and other scientific organizations, enterprises and institutions of different property categories performing investigations in the sphere of nanotechnology and release of nanoproducts.

As a condition of effective organization of working of national nanotechnological network, Nano-Net, a network for exchange of research-and-technology and engineering data, has been created.

Compared to the ERA-Net scheme, the above mentioned facts show a settled intention and practical steps towards a transition of Russia into an innovative economy where nanoscience and nanotechnologies hold a prominent place. The Program of development of nanoindustry in Russia aims at a socio-technological challenges as well at securing competencies in a prospective sense.

Evaluation and Impact: n.a.

4.3.2.3 Federal target program on nanotechnologies 2008-2015

According to the governmental program documents, nanoindustry development in the Russian Federation is carried out in such areas as nanoelectronics, nanoengineering, functional nanomaterials and high-purity substances, and others. Federal, regional, branch and departmental purpose-oriented programs providing financing in sphere of nanotechnologies and finishing of their results to a stage of industrial production are the major tools of the state support of researches and projects in area of nanotechnologies.

One of the priorities of development and stimulate the development of nanotechnology is building infrastructure nanotechnology at the federal and regional levels. Under the Federal Program "Development of Russian nanoindustry infrastructure for 2008-2010" has been tasked to develop the infrastructure within the national nanotechnology network (NNN) at the federal level and regional nanotechnology network (RNN) at the regional level.

Nanoindustry Infrastructure includes science-educational and research organization, logistics development, skills for scientific discovery and management of nanotechnology, manufacturing companies as part of the venture capital companies, technology parks, business incubators.

National Nanotechnology Network is a multilevel, multi-dimensional structure, which consists of the separate subnets on the priority directions of nanoindustry development in Russia. The structure of the RNN should include industrial and technological, financial, information, expert and consulting, and human infrastructure.
Industrial and technological infrastructure of RNN is necessary for enabling access of enterprises (mostly small) to production resources. Its elements are the centres of innovation development in the regions, the scientific and technological parks, centres of technology transfer, business incubators, engineering and innovation centre, logistics centres, special economic zone of technology-innovative and industrial-production type.
Compared to the ERA-Net scheme, the Federal target program on nanotechnologies 2008-2015 clearly aims at network creation as well as federal-regional coordination. Apparently it is well comparable with the Nanotechnology programmes of other countries in this study. The Russian FTP is a diffusion oriented programme that aspires to increase the overall competencies in this scientific field as it is perceived to be a future growth market. The closest type of CM is securing competencies in a prospective sense.
Evaluation and Impact: n.a.

4.3.2.4 FTP on Increasing the Safety of Road Traffic in 2006-2012

Coordinator: Russian Ministry of Interior

The overall objective of the Federal Special-Purpose Programme "Improving Road Safety in 2006-2012" (primary national plan of action) is to decrease the annual road fatality rate by 1.5, comparing the indicators of 2012 to 2004.
Key working areas of the Programme include dangerous driving prevention; further improvement of the driver-education system; improvement of traffic regulation in major cities; or to enhance the efficiency of governance to ensure road safety strengthening at the federal, regional and local levels among others. The 7th year-cycle Programme comprises two stages, each one based on several measures.
Stage 1 (2006-2007) contains policy measures such as a public awareness campaign, which aims to promote negative attitude toward violators of traffic rules; to take up pilot projects, aimed at substitution of highway police stations with automatic traffic-control systems, to improve technical equipment of the State Inspection for Road Safety (operates under the Department of Road Safety, Ministry of Interior of the Russian Federation); to undertake systematic studies to identify common causes of road accidents, its influence on socio-economic development; or to monitor road accidents rate and dynamism in public opinion regarding road safety issues.
Stage 2 (2008-2012) is more application oriented as it contains the following policy measures:

- Continue attach importance to construction and improvement of underground and elevated pedestrian crossings,
- Implement new road safety technologies and ensure up-to-date technical equipment for the State Inspection for Road Safety (, Ministry of Interior of the Russian Federation),
- Continue to undertake information campaigns to promote law-obedience among drivers,
- Ensure the participation of NGOs in road safety campaigns,
- Intensify activities aimed at prevention of child fatalities and injuries in road accidents,
- Improve acting mechanisms and policy to follow the observation of traffic rules by the drivers,

- develop international cooperation in the field of road safety,
- Continue monitoring road accidents rate as well the dynamism in public opinion towards road safety issues.

Compared to the ERA-Net scheme, the FTP on Increasing the Safety of Road Traffic in 2006-2012 is more devoted to setting common standards than an actual research programme. However, given the participation of various stakeholders ranging from the Department of Road Safety to police forces and other public actors the programme entails large coordination efforts. Research is supported for activities related to traffic and pedestrian management; introduce new complex plans and projects in traffic regulation. Apparently it is mainly

Evaluation and impact: The most relevant results for this moment include the purchasing of technical equipment and infrastructure development; a series of analytical and technical studies on road safety improvement were undertaken; public-awareness campaigns under common motto “Respective driving” were carried out; and a training and capacity-building programs was implemented. The total amount of financial resources allocated for implementation of the Programme in 2006-2012 is estimated at 1797 million USD. The realization of the Programme in 2009 was financed from 3 sources:

- Federal budget - 81.2 million USD,
- Federal subjects budgets – 103.9 million USD,
- Non-budgetary sources – 1.8 million USD.

5 India

5.1 Introduction

5.1.1 Economic and political trends

The federal republic of India consists of 28 states and 7 union territories and has a population of more than 1.1 Billion. Since the elections to the lower house in 2009 the country is governed by a minority coalition (United Progressive Alliance, UPA) by head of government Dr. Manmohan Singh. His coalition government is backed by various other parties. Manmohan Singh serves a second term as head of government. The political situation between India and neighbouring Pakistan remain intense. India's political system remained largely stable despite recent turmoil in November 2008, when terrorists allegedly originating from Pakistan conducted a series of attacks in Mumbai, India's financial capital.[53]

Population (Head count, 2008)	1,144 mill.
GDP per capita (in US$, 2008)	2,900 (est.)
GDP growth rate (2008)	7.35 %
Unemployment (2008)	10.4 % (est.)
R & D intensity (GERD/GDP, 2008)	0.88 %
Share of private sector R&D (2006)	ca. 30 %
Share of public sector R&D (2006)	ca. 70 %
Innovation Performance (innovation gap 2008 compared to EU-27)	-59 %

Table 7: Indicators for India at a glance

Sources: OECD (2010) Country statistical profiles, CIA World Factbook, R&D Statistics from OECD and ERAWATCH, Innovation performance data from EIS 2009

India's economy has been growing at an impressive average annual rate of more than 8 % between 2000 and 2009. The global financial crisis of 2008/09 brought a slight downturn of this dynamic but still the economy grew by 7.35 % which makes India one of the fastest growing economies next to China – despite pressing problems such as significant overpopulation, environmental degradation, extensive poverty, and widespread corruption remain challenging obstacle to development. Given these challenges, the government focuses on macro and micro economic and social problems associated with the "bottom of the pyramid".[54]
India growth was spurred by internal market dynamics instead of the "common" export led growth pattern. India's economy depends far less on exports than other countries, particularly Asian economies. In fact, the trade balance has been negative in recent years.[55]

[53] Krishna (2009)
[54] WTO (2010b), Krishna (2009)
[55] Herstatt (2008)

5.1.2 Overview on India's national innovation system

The Indian National Innovation System is heavily influenced by the Federal Government as it not only responsible for the incentives for R&D and the institutional environment (higher education etc.) but also for determining in which sectors and to which degree foreign enterprises may engage in R&D activities in India.

Under the overall administrative and executive control of the Office of the Prime Minister, the structure of S&T system operates in a co-ordinated and consultative mode of style. Policy formulation and coordination is carried out by basically three major actors: The Planning Commission (by the member in charge of S&T); the Ministry of Science and Technology (MoST) and other important ministries such as Defence (which houses the Defence Research and Development Organization (DRDO) with around 35 laboratories). The two major science agencies, Department of Space (DOS) and Department of Atomic Energy (DAE) operate directly under the Prime Minister's office. Over the last five years two advisory bodies were created (Office of the Principal Scientific Advisor to the Cabinet and the Science Advisory Council to the Prime Minister) to advise the major actors and also increase coordination between them. There are six federal departments that deal exclusively with matters of S&T (within MoST the Departments of Science and Technology, Biotechnology and Scientific and Industrial Research; and the Departments for Atomic Energy; Earth Science; and Space).[56]

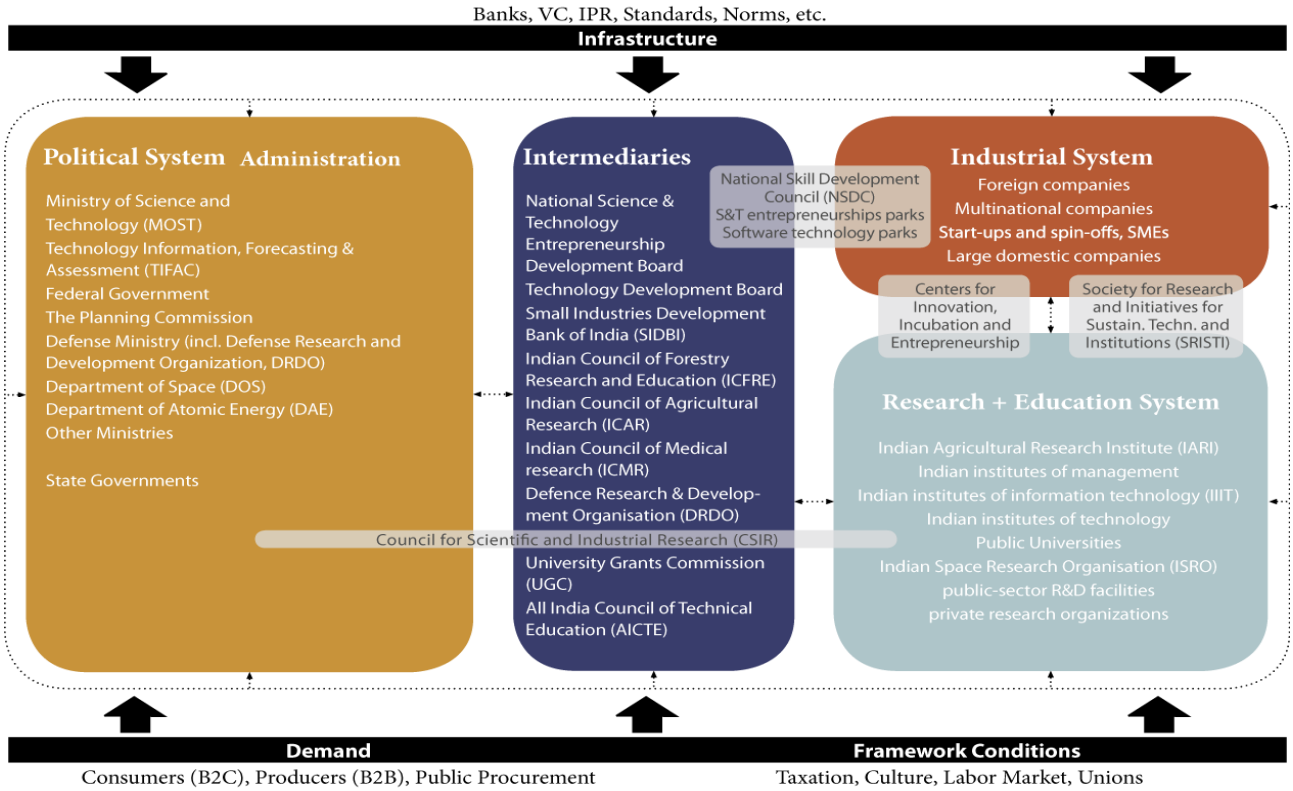


Figure 5: India's Innovation System at a glance

Source: own compilation

[56] Krishna (2009), Herstatt (2008)

The Indian Innovation System is rather fragmented and characterized by the simultaneous existence of "technological islands"[57] whose high-tech research is comparable with the one of the industrial countries on the one hand and a large mass of other research institutions, universities and colleges that have no significant research activities on the other. Over 250 foreign and transnational corporations set up R&D centres and laboratories in the country and around 50 000 professional scientists and engineers work in these foreign R&D centres in India in places like Bangalore, Hyderabad and the Delhi region. These developments can be considered as strengths of India's innovation system.

The heterogeneous and complicated structure of the Indian NIS is the result of historical events. Recent initiatives to reform the system were not successful. The Indian research system and structure of governance can be characterized as a 'top-down model' with the Federal State being the most important supporter of R&D. Over the last decade, a dominant proportion of aggregate gross expenditure on research and development, around 70 to 75 %, is met by the government sources and the rest from private enterprises. Currently the country spends roughly 1 % of GDP on science and technology. The biggest challenge remains the low (even though rising) level of private R&D which is the result of the reluctance of the vast majority of Indian entrepreneurs to engage in innovative activities and instead relying on new machinery or technologies from abroad.

5.2 Overview on Indian research and innovation policies

5.2.1 Organization and main instruments

S&T policies are conceptualized and coordinated basically by three actors: The Planning Commission, the Ministry of Science and Technology (MoST, incl. various science agencies under it) and the Scientific Advisory Bodies to the Cabinet and Prime Minister. There is no formal national innovation policy or statement announced by Indian government so far, but various other policy documents on science and technology for development and on economic growth have made reference to innovation policies. Innovation has become an important concept and is often used in a generic reference to various aspects of development and the implementation of economic and industrial policies in the country. The key document for India's S&T development is labelled "Science and Technology for the 11th Five Year Plan 2007-2012 – A Steering Committee Report" published by the Planning Commission. The budget estimates for 11th Plan indicates five fold increase to education and three fold increase to science and technology budgets for the plan period compared to the 2005-06 figures.[58]

The 11th Plan constitutes the overarching policy intent of the country. In essence, this statement explicitly spells out the public support to the S&T system involved in the generation, absorption, application of scientific knowledge for society at large in order to support industrial development and enhance the quality of life. In financial terms the major challenge is to implement the research policy commitment of spending 2 % of GDP to R&D from the current level of over 1.1 % and nearly 6 % of GDP to education from the current level of around 4.4 %. The main goals of India's new research and innovation policies is to increase the scientific and technological potential of

[57] Nassif (2007)

[58] Krishna (2009)

knowledge based institutions both in the formal sector (new and high technologies) on the one hand and micro, small and medium enterprises in the semi-urban and rural sectors of economy, on the other hand.

The main priorities addressed in the policy measures are horizontal measures in support of financing (due to the lack of venture capital funding from the business enterprise sector and other private foundation sources) and secondly to support innovative start-ups. India has launched two major schemes for biotechnology and industrial research for SMEs. These were also implemented since a lot of the R&D results in major industrial research agencies (such as the CSIR, which houses 38 national laboratories) remain unexploited.

The main target groups of federal policies are pharmaceutical, biotechnology and agriculture sectors mainly focusing on SMEs. R&D institutions and individuals who are making efforts for start-ups are the second target group. Regarding the aspects of innovation process, much of the emphasis has been given to up-scaling R&D from the laboratory to commercialization. The financial support in this respect is given to firms and S&T institutions.

5.2.2 Main objectives and major trends

In contrast to many developing countries the decision to liberalize trade and implement other economic reforms went hand in hand with policies with the aim of improving the innovation system. In fact, most of the technological programs oriented towards supporting R&D were maintained or even strengthened (e.g. in the areas of atomic and space research). For almost four decades, basically until the trade liberalization during the 1990s, S&T policies were based on strengthening the supply side rather than the demand side of innovation. The result was a large R&D base across a range of S&T areas both in "big science" (space, defence and atomic energy) and high technology such as chemicals and pharmaceuticals, biotechnology and ICT software, among other areas. Only in the last few years the government has begun to focus on the demand side of innovation by implementing a number of support schemes incl. the support of university – industry partnerships or researcher mobility.[59]

India is presently at a crossroad since the high growth rates of the service sector, compared to manufacture and agriculture sectors, have strongly increased the demand for skilled labour. This aspect is particularly relevant since a significant portion of the labour employed in IT services comes from the higher castes of the population. Therefore, the future success of this sector is determined by extending the appropriate technical education and training to other social groups.[60]

It needs to be acknowledged that the government proportion is witnessing a downward trend and business enterprises have been increasing their proportion gradually over the last years. The economic crisis has had varying influences on different for which any outlook on the trends concerning national innovation performance needs to take into account sectoral differences. The most impressive trend in innovation performance from the public research system has come from the Indian Space Research Organization (ISRO) which entered into an age of commercial design and launch of satellites. The second significant trend is the emergence of India's business enterprise sector with a globally competitive edge through innovations in pharmaceuticals, the

[59] Nassif (2007)

[60] Nassif (2007)

automotive sector, software, telecommunications and biotechnology. Last but not least, the Indian telecom market is one of the fastest-growing markets in the world in 2009 in terms of subscribers, behind China. The telecom sector registered a growth of 103 % during the fiscal year 2008/09 as compared to the previous fiscal year.[61]

Indian innovation policies face various immanent challenges. The first regards the training of human resources as the large private enterprises with technological capabilities in most of the above fields of high technology industries are in continuous need of a highly skilled workforce. Secondly, institutional measures which promote university-industry partnerships are a big challenge in the Indian university system. This includes the reorganization of research teams to foster networks between universities and other relevant actors. Other challenges include the domestic digital divide between urban centres of excellence and marginalized rural regions as well as the formulation of "inclusive" innovation policies in order to meet the demands of the poor and the informal workforce

5.3 The Coordination of Research Policies and Programmes in India

5.3.1 Introduction to ways and rationales for coordinating and pooling resources

The Indian innovation policy is rather difficult to characterize in terms of mission, diffusion or excellence orientation. India's innovation policy is characterized by large scope of issues because finds itself at the crossroads of becoming a "developed country sooner or later" (Department of Science & Technology/Ministry of Science & Technology 2010: 7). Therefore policy has to address several issues at the same time: help solving societal challenges (e.g. rural poverty), trying to gain knowledge in future technologies with high market potential (e.g. biotechnology or nanotechnology) and competing with world-class research facilities outside the country in the industrial countries. The current 11th Plan for Science and Technology for the 2007 – 2012 period acknowledges this situation and gives a broad spectrum of policy rationales and guidelines for the direction of R&D activities (Government of India 2006). With regard to the industrial countries the document emphasizes the need to catch up in the technological fields developed by the industrial countries and complementing them with an Indian perspective. Self-directed basic research should receive substantially increased support.

The plan makes two explicit references to CM without defining the term, however. First, it states that the academia lacks a critical mass of experts and specialised technical infrastructure to collaborate with industry. CM in this context refers to the gathering of an overall amount of researchers. India does not dispose of enough researchers to conduct excellent basic research at universities and applied research for industry at the same time. The second aspect refers to institutional factors. Apparently in the case of biotechnology the country counts with a "critical mass" of researchers, but they do not find a favourable research environment in their home institutions. In others words, the effects of critical mass are hindered by institutional shortcomings.

[61] Krishna (2009)

Currently, India faces many challenges at the same time. While some sectors are recognized on a worldwide scale (such as the software sector) others are lagging behind. The XIth Plan envisages that India must try to become “Global Innovation Leader” across all S&T areas and highlights the objectives and challenges for achieving a broad based higher economic growth rate in agriculture, industry and services, as well as the measures required for a more inclusive development. This balancing act of developing first class knowledge to compete on the global scale and at the same time catering for technological social inclusion is the main challenge for the Indian Innovation System at the moment.

5.3.2 Selected Initiatives and Programmes

On the one hand there are clear sign for a widespread **mission orientation.** The reasons for this have to do with the country's deep societal challenges such as poverty, malnutrition and urbanization. **It is aimed to quantitatively and qualitatively expand the Mission mode and multi-partnership projects between S&T actors, industry and the ministries, especially the socio-economic ones**. One example of the mission orientation is the recently started "WAR on Water mission" (Winning, Augmentation and Renovation of Water resources) of 2009.[62] The goal of the Technology Mission WAR for water is that successful technological solutions are disseminated that could ultimately benefit up to 5 million people. The programme is in line with the Water Technology Initiative (WTI) Programme which is managed by the Department of Science & Technology (DST) within MoST. It aims to promote R&D activities to provide safe drinking water at affordable cost and in adequate quantity. Research should provide holistic solutions to the problem of water contamination and water scarcity.[63] Other mission oriented programmes include the Solar Energy Research Initiative[64] or the Nanoinitiative (see below under life sciences). Some of the programmes fall within the scope of the socio-economic ministries. In order for the programmes to be successful the existing modes of interaction between S&T system and the socio-economic ministries must be improved. Coordination of programmes has been an issue in the past and both spheres have been working rather isolated.

On the other hand India has a tendency to establish Centers of Excellence (CoE) in various domains. Since India is not a world leader in any field it is aimed to built up the necessary competencies and capacities in selected areas - whether it is in agriculture or in export or in certain technology sectors (Biotechnology, Nanotechnology) or in the industrial field.

Another interesting cross-cutting programme is called "Intensification of Research in High Priority Areas (IRHPA)"[65] which joins elements of mission orientation with considerations of excellence. In this programme and complimentary to the normal R&D projects, the Science and Engineering Research Council (SERC) promotes the creation of core groups/units around an outstanding scientist, national facilities and nationally coordinative programmes in multidisciplinary areas of high priority areas which are defined by a public entity. They are generally supported under this scheme as Coordinated Programmes. All measures are subject to a countershare from the concerned agencies/institutions.

[62] http://dst.gov.in/scientific-programme/plan-document.pdf <15.01.2011>

[63] http://dst.gov.in/scientific-programme/t-d-wti.htm

[64] http://dst.gov.in/scientific-programme/t-d-solar-energy.htm

[65] http://www.serc-dst.org/irpha.htm#ob

Apparently, the S&T system continues to be in a need for improvement. The attitude of many administrators and scientists alike seems not to be compatible with the requirements of a research friendly environment. The 11th plan is quite outspoken and identifies "a clear need to restructure and reengineer most of these [structures of the S&T system]" (Department of Science & Technology/Ministry of Science & Technology 2010: 24) in order to meet future challenges and secure economic growth.
Further challenges that are important for Critical Mass include

- Human Resource Development,
- Research should be carried out on mission mode rather than on discipline mode by introducing the concept of “Directed Research” (institutionalization of public-private partnerships),
- The coordination of S&T policies with the federal states. The demand for S&T inputs and to facilitate generation of joint programmes with industry, NGO’s, etc. coming from the State governments and their agencies must be increased,
- Industry must increase its share in overall spending on S&T. The goal set forth by the government is to spend at least 2 % of GDP on S&T. Without increased spending on R&D by the private sector the mere expansion of the public infrastructure will not suffice.

The following table gives a rough overview of the requested fund in the 11th Plan for S&T. The overall funds total to Rupees 121.970 crores[66], some € 19 billion, for S&T activities.

[66] Crore is an Indian arithmetic unit meaning 10,000,000

Sr. No.	S&T Departments/ Agencies	Xth Plan Outlay	Xth Plan Actual	XIth Plan Proposed By the Dept	Additional budget recommended by Working Groups	XIth Plan Reco-mmended
1.	Department of Atomic Energy	1003.00	3200.00	11010.53	160.00	11170.50
2.	Department of Biotechnology	1450.00	1680.23	12000.00	650.00	12650.00
3.	Ministry of Earth Sciences	1540.25	1636.24*	12008.91		12009.00
4.	Department of Scientific & Industrial Research (including Council of Scientific & Industrial Research)	2574.00	3089.00	18733.00	200.00	18933.00
5.	Department of Space	13250.00	11502.00	36750.00		36750.00
6.	Department of Science & Technology	3400.00	4398.81	19300.00**	11160.00	30460.00**
	Total		25506.28			121972.50

* This figure includes allocations to IMD, NCMRWF and IITM when they were under DST

** This is due to several new programmes, particularly those related to attracting young people to careers in science, suggested by the Steering Committee to be piloted through DST and the NSERF. The factor of increase for DST without these additionalities is given in parenthesis in the last column.

Table 8: Proposed Plan Allocation: Central S&T Departments/Agencies

Source: http://dst.gov.in/scientific-programme/plan-document.pdf <15.01.2011>

Life Sciences play unarguably an important role in the portfolio of the Indian support system. There are two rationales which are comparable with the notion of CM in the European context that are of importance: First, the creation of world class research and thus resembling a pattern of excellence and second, a pattern refers to solving socio-economic challenges. Life sciences are of great importance for the growth path of the Indian economy. The following Table 9 gives an idea about the number of projects funded by DST in the area of life sciences and other areas in the most recent period of 2009-2010.

	Nr. of projects sanctioned	Amount in R $ lakhs	In €[67]
Chemical Sciences	105	3261,1	51.668.200
Life Sciences	135	5308,8	84.101.500
Physical Sciences	74	2578,9	40.846.600
Earth & Atmospheric Sciences	60	1472,1	23.322.800
Mathematical Sciences	34	289,3	4.579.000
Engineering Sciences	119	3120,2	49.434.200

[67] Exchange rate Indian Rupies to Euro as of 02.02.2010: 0,01574

Total	527	16030,4	253.984.000

Table 9: Overview of the funded projects by the Department of Science and Technology, 2009-10

Source: http://dst.gov.in/about_us/ar09-10/annual_report_2009-10.pdf

5.3.2.1 Mission on Nano Science and Technology

The Mission on Nano Science and Technology shows certain similar features regarding CM as the EU ERA-Nets. The Mission on Nano Science and Technology (Nano Mission) is an umbrella programme that was launched in May 2007 to promote R&D in this research field in a broad fashion. Central goals of the programme are:

- Basic research promotion: Funding of basic research by either individual scientists and/or groups of scientists as well as the creation of CoEs for conducting cutting edge fundamental research necessary to control and operate at the nanoscale,
- Infrastructure development for carrying out first class research: Nano research is still rather cost intensive. For an optimal use of expensive and sophisticated equipment the programme foresees to implement a chain of shared facilities across the country,
- Development of applied nanotechnologies: To support the application of nanotechnologies the programme supports application-oriented R&D Projects and various forms of transfer institutions such as Nano Applications and Technology Development Centres or Nano-Technology Business Incubators etc.,
- Human Resource Development,
- International collaboration.

The Nano Mission is open for application (proposals) for financial support throughout the year. Decisions on funding are taken periodically. Currently, financial support is granted for R&D projects from individuals scientists or a group of scientists for normally 3 years; for the establishment of CoEs for 5 years; application oriented joint industry academia projects for 3-5 years with a “diserable” countershare of industry.

Compared to the ERA-Nets, the Nano Mission **does not involve sub-federal actors**, but is a horizontal activity at the federal level, involving departments and agencies with nanotechnology R&D budgets and nanotechnology facilities. Just as the US Nano programme, the Indian Mission on Nanotechnology aims at **reducing duplication of research and making a better (synergetic) use of infrastructures**.

Evaluation and impact: The Nano Mission is a continuation of a Nano-Programme that started 2001. In this first phase DST support 130 projects of individual scientists, the establishment of sophisticated equipments at various locations in the country, setting up a decentralized network of 11 Centres of Excellence across the country as well as seven application oriented Centres for Nano Technology. Although the calls remain national, India has signed various international cooperation agreements with Germany and the US in particular, but also with Japan, Russia and the Ukraine.

5.3.2.2 Biotechnology Support programmes

The Biotechnology support programmes are handled by the Department of Biotechnology within DST. Biotechnology is one of the strategic priorities of the Indian government regarding the creation of first class knowledge intensive research and industry. Thematically the Biotechnology support includes the following:

- Agricultural Biotechnology – Crops,
- Plant Biotechnology,
- Animal Biotechnology,
- Aquaculture and Marine Biotechnology,
- Seribiotechnology,
- Medical Biotechnology,
- Stem Cell Biotechnology,
- Environmental Biotechnology,
- Basic Research in Modern Biology,
- Bioengineering,
- Human Genetics and Genome Analysis ,
- Bioinformatics,
- Microbial and Industrial Biotechnology.

The funding is ample in scope than the Nano-Programme. Apart from normal R&D projects and the support for CoEs, the Department of Biotechnology also counts with mission oriented programmes such as the so called "Mission Mode Programme on Biofuels and Bioenergy" (research on Bioethanol). Additionally the aspect of poverty alleviation and food security is treated very prominently as the funding schemes Biotechnology for Societal Development and on Food and Nutrition Biotechnology show. Last but not least the department has SME focused funding schemes which show strong similarities with the US SBIR called SBIRI for public private partnerships. Finally the Department of Biotechnology funds the planning, construction and installation of Biotechnology Parks in form of PPPs as well as it supports incubators for Start-ups.

The DBT programme to increase and strengthen institutional research capacity in areas of Biotechnology through CoEs explicitly mentions CM. The support is directed towards the expansion of faculty research capabilities and the increase of research infrastructure around a distinguished peer-reviewed researcher. "A critical mass of young scientists around a leader will be expected to be developed either through involvement of existing scientists or by infusion of fresh talent. Development of a critical mass of investigators is envisaged to enhance their competitiveness in a specific research area that accelerates the rate at which those investigators compete for other complementary external peer-reviewed research grant support."[68]

Compared to the ERA-Net scheme, the Indian Biotech Programme resembles a thematic umbrella programme. It is comparable to the Brazilian one outlined above.

[68] http://dbtindia.nic.in/uniquepage.asp?id_pk=20

Evaluation and impacts: No impact assessment

5.3.2.3 Mega Facilities for Basic Research

Another research driven action is the natural sciences is "The Mega Facilities for Basic Research" programme. It was launched to either build large research facilities in India or to participate in building and using such facilities abroad. The scale and scope of such facilities make them multi-agency, multi-institutional and most of the times international in character. Additionally they are very long-term projects. India's active participation in experimental programmes at CERN, Geneva continued during the 2009-2010 period. Projects were funded, jointly with the Department of Atomic Energy, for taking part in the CMS (Compact Muon Solenoid), ALICE (A Large Ion Collider Experiment) experiments at CERN and in the establishment of the LHC (Large Hadron Collider) Computing Grid.

Compared to the ERA-Net scheme, the Mega Facility Programme of the Indian government clearly points out to **frontier research**. The programme aims to **foster international cooperation** in fields of natural science where individual research facilities are too costly. There are **no calls but international cooperation agreements** about the usage and the course of action of these facilities. It is one example of India`s international strive for **excellence**.

5.3.2.4 Climate Change Programme

The ambitious National Action Plan on Climate Change (NAPCC) joins eight different national missions that all should contribute to a better understanding of the phenomena of climate change and also developing solutions to continue with the impressive economic growth and simultaneously reduce emissions. Science plays a pivotal role in the strategy and the MoST is responsible for coordinating two out of the eight national missions launched under the NAPCC. The plan identifies eight core "national missions" running through 2017 and directs ministries to submit detailed implementation plans to the Prime Minister's Council on Climate Change.

MoST coordinates the National Mission on Sustaining Himalayan Ecosystem (NMSHE) and the National Mission on Strategic Knowledge for Climate Change. The NMSHE proposes to work towards initiating research & development in the relevant areas, taking up appropriate policy measures and time bound action programmes to address sustenance and ecological resilience of the Himalayan region and ensure the continued provision of key ecosystem services.

The Mission on Strategic Knowledge for Climate Change has as its core objective to set up a data sharing policy framework for building strategic knowledge among the various arms of the Government. The programme outline makes also explicit reference to CM when it calls for setting up networks of knowledge institutions "after investing critical mass of physical, intellectual and policy infrastructure resources, creation of new dedicated centres within the existing institutional framework, building international cooperation on S&T for climate change agenda through strategic alliances and assistance to the formulation of policies for a sustained developmental agenda within a responsive climate change framework and inputs to the Ministry of Environment and Forests and Ministry of External Affairs."[69]

Compared to the ERA-Net scheme, the Climate Change Programme is a sub-programme of the National Action Plan on Climate Change. The programme coordinates and supports research

[69] http://www.dst.gov.in/scientific-programme/td-climate.htm

activities that contribute to a better understanding of the effects of climate change for India and that contribute to the overall mission. The programme not only raises awareness among relevant actors but also coordinates actions among key institutions, international partners and the development of adequate policies. The participation of each partner is not definable.
Evaluation and impact: The National Action Plan on Climate Change was implemented in 2008. Therefore there is data on the impact yet.

5.3.2.5 Technology Promotion, Development and Utilization (TPDU) Scheme

The Indian experience shows that the central state has always played an important role in the development of the national industrial sector. This was true especially before the economic liberalization of 1991 when the state was the single most important actor in terms of industrialization of the country. Today the support is less pronounced but still there is a large variant of support programmes for industry mainly managed by the Ministry of Commerce and Industry. Therefore it is impossible to give a satisfying overview of all the available instruments. The focus here will be on programmes that either explicitly mention CM or are geared towards industrial technologies.
The Department of Scientific and Industrial Research (DSIR) as one of the departments of the MoST supports industrial research for indigenous technology development, utilization and transfer.[70] DSIR has dozens of different schemes regarding industrial technologies and the use of technologies in general. Most prominent is the Technology Promotion, Development and Utilization (TPDU) Scheme which is divided into several sub-programmes ranging from the Industrial R&D Promotion Programme to Technology Development and Utilization Programme for Women. The incentives vary from programme to programme and include tax exemptions for the use of domestic technologies and grants. Depending on the programme various costs are supported, even the running costs that incurred directly as a result of proposed research activity.
The Science and Engineering Research Council (SERC) of DST is now the single largest support system for promoting basic research in all areas of science and engineering. SERC is the most important source for open-ended basic research in the academic sector; about 44 % of the extramural research funding in Universities comes from SERC and the rest from 18 other Departments/ funding agencies.[71] The objectives of SERC are

- To promote research in newly emerging and frontier areas of science and engineering including multidisciplinary fields,
- To selectively promote the general research capability in relevant areas of science and engineering taking into account capability of the host institutions,
- To encourage young scientists to take up challenging R&D activities,
- To give special encouragement to active scientists from relatively small and less endowed University Departments and Institutions.

The goal of SERC's project support is to increase and expand knowledge in basic research, excellence in science & engineering, innovation and promotion of selected areas, and the

[70] http://dsir.gov.in/a_report/english/2009-10E/toc0910e.htm
[71] http://dst.gov.in/about_us/ar09-10/annual_report_2009-10.pdf

encouragement for industrial partnership in projects under engineering and technology. SERC raises awareness in so called "Thrust areas" which are considered to be potential areas of future growth (Molecular Biophysics, Chronobiology, plant animal relationships, etc.). The goal is to built up competencies in these field, but as far as it possible to say from abroad it not yet a process of self-sustained dynamics in these fields but moreover some prospective studies.
SERC grants funding for equipment, human resources for scientific and research projects, supplies & consumables, and travel costs. There is also support for IPR and Patenting. Project proposals can be submitted anytime throughout the year.

5.3.2.6 S&T entrepreneurship development Programmes

Horizontal activities which aim to foster Science and industry relations across sectors include among others the National Science and Technology Entrepreneurship Development Board (NSTEDB) which aims to support technology based and knowledge driven entrepreneurship among S&T persons. One of NSTEDB's most prominent schemes is the support for Technology Business Incubators. The programme has been implemented in the 1980s. Even though the development seemed to have been rather slow there are now over 50 incubators are functioning across the country. As it says on the homepage "Efforts are underway to bring the TBI's magnitude much closer to a critical mass."[72] This clearly refers to a prospective view on CM in terms of securing competencies in a rather broad vision. Clearly the goal here is to increase the number of spin-offs and technology intensive

5.3.2.7 S&T Programmes with a focus on poverty alleviation

One of the most interesting aspects of the Indian innovation System is the focus on poverty alleviating aspects. Many of the efforts of the countless agencies and department is surely devoted to academic excellence and frontier research, however there are also various programmes that aim to contribute to improve the living conditions of millions of people living below the poverty line. Most of these programmes can be classified as health research. The continuous efforts over the last five year Science and Technology Plans yielded several successes in form of the development of new and most notable cheaper drugs (generica).
Another activity is called Technology Systems Development (TSD) Programme that supports the development and integration of technologies to evolve into technology systems both in the advanced or emerging areas and in traditional sectors. The focus of TSD is on inter-disciplinary, multi-institutional technology feasibility and the development of products or technologies needed for a specific end use. The fundamental goal of the programme is to develop products and technologies benefit a wide range of beneficiaries. In short the TSD Programme aims to:

- Develop and integrate technologies following a holistic approach in identified areas,
- Promote application of advanced technologies to socio-economic problem solving,
- Promote modernization of traditional technologies, tools and skills,
- Facilitate enhancement of quality and performance of traditional and non-traditional production factors.

[72] http://dst.gov.in/about_us/ar09-10/annual_report_2009-10.pdf

The Science For Equity Empowerment and Development Programme has the broad objectives of providing opportunities to motivated scientists and field level workers to take up action oriented and location specific projects aiming towards socio-economic improvement of poor and disadvantaged sections of the society through appropriate science and technology interventions especially in the rural areas. Under this program efforts have been made to associate concerned National Labs or other specialist S&T institutions with each major program so as to build-in expert input, utilize national S&T infrastructure and link it up with grassroots S&T initiatives.
Compared to the ERA-Net scheme these programmes that focus on improving the living conditions of large segments of society are rather differently conceptualized. They certainly do aim at solving a socio-economic challenge but their approach is not based on excellence or securing competencies as defined here, but moreover they support technologies at the very low end by coordinating the actions of ministries and especially local agencies.
Evaluation and impact: Given the multitude of actions it is difficult to assess the overall impact.

5.3.2.8 National Agriculture Innovation Project (NAIP)

The Indian Council of Agriculture Research (ICAR, located within the Ministry of Agriculture) launched this programme in 2006 with financial support of the Worldbank. The goal of the programme is to strengthen the competitiveness of the countless rural Indian farmers by supporting collaborative development and the application of agricultural innovations by public research organizations together with farmers, the private sector and other stakeholders. The programme is implemented in a highly decentralized manner. The innovation in governance of NAIP is that the implementing consortia/ institutions will be facilitated to work with full freedom and accountability and without interfering controls of the project authority once they have entered into partnership and clear agreements with the ICAR. Lead by a National Steering Committee that manages the grants of the NAIP and formulates the policies,
To build capacity to undertake basic and strategic research in frontier areas to meet challenges in technology development in the immediate and predictable future
Compared to the ERA-Net scheme, this programme is somewhat unique inasmuch as it is clearly focused on poverty aliviation. Still, the main aims of NAIP such as network creation and aiming the raise the competitiveness of the agricultural sector by increasing the use of technologies is similar to securing competencies and to reach self-sustained dynamics. Policy coordination occurs with private stakeholder as well as with the rural federal states.
Evaluation and impact: The programme has a total budget of € 166 million.[73] Given the short period the programme is in place no impact assessment can be made yet.

5.3.2.9 Policy coordination with the States

As a federal country there is a strong need for policy coordination between federal and state level in India. The states count with the existence of State Councils for Science & Technology that have now been set-up in all the States and Union Territories. The States and the federal level need to find ways to align their policies in order for them not to have a contrary effect. This requires various consultations. The consultations result in joint programmes focusing on multi-sectoral approaches to rural and regional development. Those approaches that could significantly improve

[73] http://proinno.intrasoft.be/index.cfm?fuseaction=wiw.measures&page=detail&ID=9482

the existing socio-economic conditions may also receive funding from various federal departments including DST.[74] The public consultation process that renders at best a common vision of the future course of scientific issues for economic and social development is close to what in the EU is called joint programming. States and central government are involved in a negotiation process about the priorities and strategies. However, it is somewhat difficult to an assessment of this process regarding the actual possibilities of sub-national units to influence the joint programming.

[74] http://dst.gov.in/scientific-programme/s-t_scst.htm

6 China

6.1 Introduction

6.1.1 Economic and political trends

Undoubtedly, China's economy is still rapidly growing. Growth has been hampered, too, by the worldwide recession in 2008, but is still remarkably high at 9 %. China's innovative performance shows similar trends. It is still about 31 % behind the EU average, however is catching up quickly, considering that the innovation performance gap has been at 39 % only three years ago in 2005. For example, regarding patent counts, China's innovation performance has increased by 21.4 % in 2006 from the previous year. Compared to other BRICs countries, China is the fastest growing and catching-up economy.

Population (Head count, 2008)	1,337.4 mill.
GDP per capita (in US$, 2008)	6,100 (est.)
GDP growth rate (2008)	9.01 %
Unemployment (2008)	4.2 % (est., urban areas only)
R & D intensity (GERD/GDP, 2008)	1.54 %
Share of private sector R&D (2008)	73.3 %
Share of public sector R&D (2008)	24.7 %
Innovation Performance (innovation gap 2008 compared to EU-27)	-31 %

Table 10: Indicators for China at a glance

Sources: OECD (2010) Country statistical profiles, CIA World Factbook, Chinese Acadamy of Sciences, Trendchart (GDP growth rate, Science and Technology Indicators), Innovation performance data from EIS 2009

Investment into R&D activities has increased again in 2008 and is now at 1.5 % of the GDP.[75] China has been increasing R&D expenditure since the 1990s and overtook Japan in 2005 as the second largest investor in R&D, second only to the USA.[76] In China's Medium- and Long-Term S&T Development Plan, the government's R&D intensity targets are to reach 2.0 % in 2010 and 2.5 % in 2020.[77] The number of researchers in China increased by 77 % between 1995 and 2004 and reached 926,000 in 2004, also second to the USA.[78]

[75] Tang (2009); EIS 2009.

[76] Measured in PPP$, cf. Lang (2009), "Basic characterization of the research system"

[77] Lang (2009), "The relative Importance of Research Policy".

[78] Lang (2009), "Basic characterization of the research system"

The formulation of the next (12th) 5 year plan for 2011-2015 is being worked on (as of January 2010). Goals are, among others (stated by Xu Xianping, Vice Director of National Debt & Reform Commission):[79]

- Enlarging domestic demand for fast, smooth development,
- Deepen income distribution reform, increase incomes for farmers and urban low salary earners to support enlarging domestic consumption,
- Support employment and entrepreneurship,
- Stress innovation, energy conservation and environmental protection.

6.1.2 Overview on China's national innovation system

China's innovation system can be characterized as a top-down structure. Figure 6 depicts a schematic representation of the main actors in the political system, the industrial research system, and the public research and education system. Actors which perform intermediary functions are highly dependent on central political steering. There is hardly a subsystem of intermediary actors with a degree of independence comparable to other innovation systems.[80]

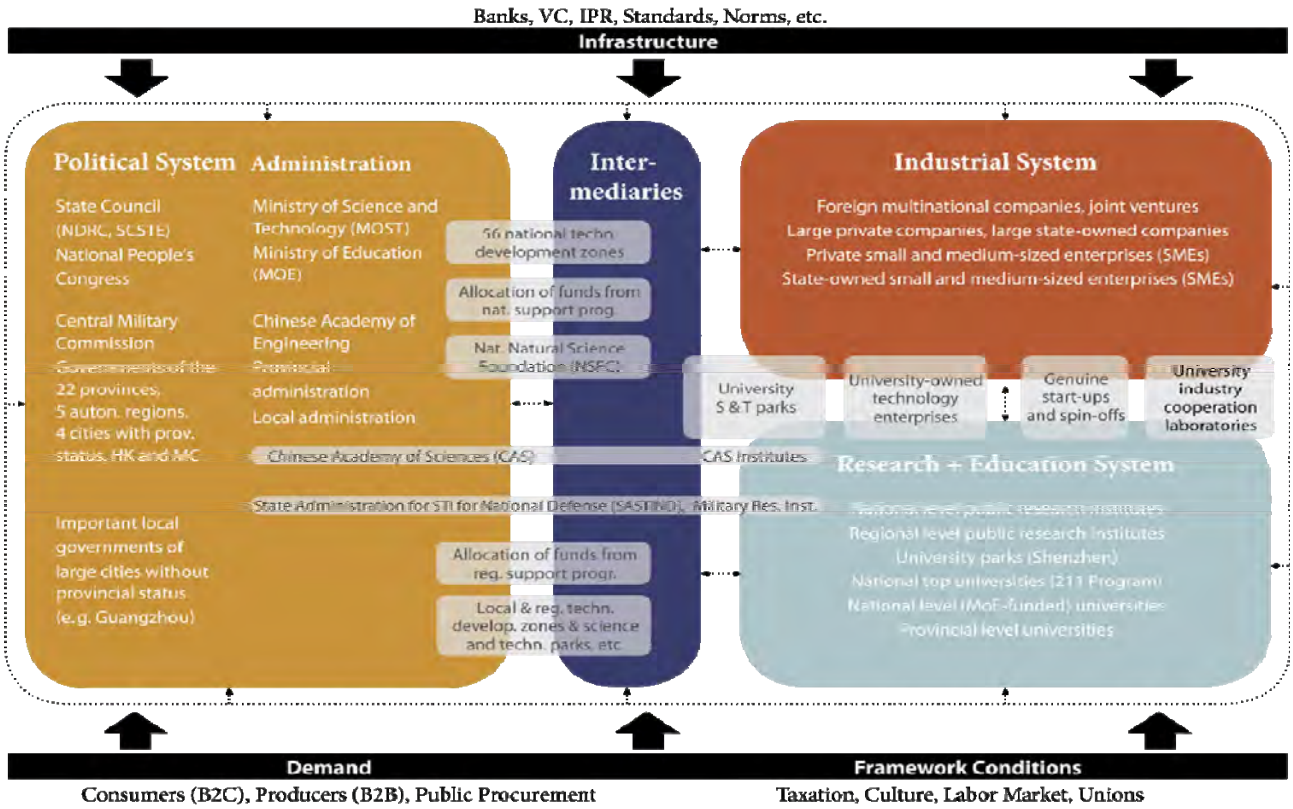


Figure 6: China's Innovation System at a glance

Source: Kroll et al. (2008:172).

The National Steering Group for S&T and Education in the **State Council** is the highest ranked organisation in China coordinating all education, research, and innovation related activities.

[79] CCTV Online source at http://english.cctv.com/program/bizchina/20100119/103613.shtml.

[80] This kind of representation has its origins in the graphical illustrations of the national innovation system concept by Kuhlmann and Arnold, *Norwegian Innovation System*, (2001).

It has nine member ministries or agencies:[81]

- Ministry of Science and Technology (**MOST**): most important player, leading ministry for S&T coordination, and implementation,
- Ministry of Education (**MOE**): policies R&D in universities, research talent,
- Ministry of Finance (MOF): fiscal policies for corporate R&D,
- National Natural Science Foundation of China (**NSFC**): develops S&T programmes and provides funding for basic and some applied research,
- Chinese Academy of Sciences (**CAS**): two roles: national advisory body as well as research performer with own research institutes,
- Chinese Academy of Engineering (**CAE**): advice for government (technological foresight),
- National Development and Reform Commission (NDRC): develops strategies (e.g. the 5 year plans) and policies with a focus on the economic and social aspects of S&T,
- Commission of Science Technology and Industry for National Defence (**COSTIND**, formerly SASTIND, see Figure 1): manages defence R&D activities,
- Ministry of Agriculture (MOA): manages agricultural R&D.

There is an initiative for reorganising the members of the State Council: A new Ministry of Industry and Information (MII) shall be set up, which shall comprise the Ministry of Information Industry, the COSTIND, the NDRC, the Information Office of the State Council as well as the State Tobacco Bureau. COSTIND will lose its status as a ministry and will be renamed to Science Technology Industry for National Defence Bureau (STINDB).[82]Since the Chinese economy has started to open up to market mechanisms, there is also a development in the innovation system towards more decentralisation. Research institutions are being given more authority to set their own research activity agendas. **Research institutes** and **universities** are the main performers of research, although this is concentrated on a few flagship sites, while the vast majority of universities concentrates on teaching. Public research performs not only in basic research, but also in the applied field, whereas the overall research performance of the **business sector** "is still lagging due to the historical production-orientation of industry in China. However, the transformation of state-owned research institutes into enterprises, starting from 1999, has strengthened R&D capabilities in industry."[83] In order to encourage R&D activities and promote technology transfer and commercialisation, **high-tech zones** and incubators have been established, inspired by the Silicon Valley model in the US. Universities and research institutes create **spin-off** companies, through which they commercialise technology and the R&D products developed in their research labs.[84]
The reform development resulted also in the decentralisation of decision-making and a hence stronger involvement of **sub-national institutions** in innovation policy-making. Local S&T strategies are often not orchestrated with central policy.[85] This kind of leverage has been possible, because of the tiao-/kuai-principle, which on the one hand implies that the organization at the sub-national level mirrors the central level including vertical linkages to the departments at the

[81] Lang (2009), "Brief description of the structure of the research system "; Mu (2004); Kroll et al. (2008: 173ff.); OECD (2008: 428ff.)
[82] Tang (2009).
[83] Lang (Lang 2009), "Basic characterisation of the research system ".
[84] Tang (2009), "Interaction between Innovation and Research Policies "; see also Kroll et al. (2008); OECD (2008: 99ff.).
[85] Kroll et al. (2008: 171).

central level (tiao). On the other hand the local government has its own budget and hence leverage to set priorities (kuai).[86]

6.2 Overview on Chinese research and innovation policies

6.2.1 Organization and main instruments

This section gives a general introduction into the policy-making of Research, Technology, Development and Innovation (RTDI) policies and programmes, and the main instruments of RTDI policy. The specific issue of coordination of sub-national policies is being dealt with in section 6.3.

The ERAWATCH monitoring reports on policy-making that the "Ministry of Science and Technology (MOST) is the leading ministry in terms of formulating S&T policies. Other ministries also have the right to formulate and implement S&T policies relevant to them. Policies can be proposed by an individual ministry independently, or by several ministries jointly. Policies implemented jointly by ministries are more influential than those implemented by single departments. For instance, MOST can promulgate policies independently under its own jurisdiction, but if MOST wants to have fiscal policies to promote industrial R&D such as taxation treatments or discount loans, it has to work together with Ministry of Finance, Bank of China or other related departments. Policies and programmes can be promulgated at the ministry level, the State Council level, or the National People's Congress level, and are more influential and significant if they are approved at the latter two levels."[87]

"The Ministry of Science and Technology is the leading ministry in S&T policy design and is also the main implementation unit. It operates S&T programmes and provides funds to R&D activities. The National Natural Science Foundation of China has a similar function in managing programmes and research funds. The Chinese Academy of Sciences is another important executive agency, which manages over 80 research institutes and is the major research performer in China."[88]

Main instruments of current research policy in China include the following: [89]

- Increasing R&D expenditure, not only by the central government, but also by local government and industry,
- Engaging in international R&D cooperation,
- Encouraging industrial R&D activities by providing fiscal incentives and promoting academic-industry partnership,
- Providing research grants to key research programmes,
- Attracting high quality human resource by setting up funds for excellent researchers,
- Setting up funds to promote the development of universities and research institutes.

More particularly, the promotion for establishing R&D subsidiaries overseas is unique. This will lead to an increased presence of Chinese technology companies in worldwide business and technology cluster (Schwaag Serger/Breidne 2007: 149).

[86] Cf. Kroll et al. (2008: 178).

[87] Lang (2009), "Government policy making and coordination".

[88] Lang (2009), "Actors in policy implementation ".

[89] Cited from Lang (2009), "Main instruments of research policy ".

6.2.2 Main objectives and major trends

China´s technology policy is geared towards one over-riding objective: **economic growth**. At the present state of development this explosive growth is associated with low- and middle tech export-oriented industrialization (Liefner 2008: 4f.). The computer industry is a good example. China has to import 24.6 % of the (high valued) electronic components to produce labour-intensive PC products with an export volume of 23.8 % (Liefner 2008: 8). Indeed Liefner (2008: 10) shows that Chinese firms involved in foreign cooperations are more innovative than those only active on the national market (41,3 % compared to 26,3 % share of new products on total revenue). This proves that, foreign direct investment exports knowledge. This process also promotes the innovation system at the coast side and increase the regional gap with China´s backward areas. In future directions China´s innovation system will struggle with bridging the gap for efficiency. So economic growth is tied both to stabilize growing inequality and as well as to achieve global economic competitiveness.

China's S&T policy has shifted its focus from technology transfer from abroad nowadays to **achieving original innovation in a number of core technologies** such as information, material and aerospace.[90] As innovation has become increasingly popular, most R&D activities are associated with the task of commercialisation. This might lead to less attention for applied/ basic research.[91]

The goals of research policy in the next fifteen and five years are specified in two main policy documents: the Medium- and Long-term National Plan for Science and Technology Development 2006-2020 and China's National S&T Development Plan for the 11th Five-year Period 2006-2010 (and its successor for 2011-15 respectively).[92] Some quantitative goals are proposed in these plans. These include:

- R&D/GDP reaches 2 % in 2010 and 2.5 % in 2020,
- The level of reliance on foreign technology drops to 40 % in 2010 and 30 % in 2020,
- the share of contribution to economic growth from S&T reaches 45 % in 2010 and 60 % in 2020,
- Being a "Top 10" country in 2010 in terms of the number of scientific publication citations and a "Top 5" country in 2020,
- Being a "Top 15" country in 2010 in terms of the number of granted invention patents and a "Top 5" country in 2020.

In particular the 15-year-plan can be seen as promoting a change in understanding of innovation, shifting from a linear understanding of innovation processes to a more interactive, systemic view on the process. "In essence, the new policy document mirrors the determination to move from a comparatively uncoordinated piecemeal style of STI policy-making to a better coordinated whole-of-government policy approach."[93]

The Medium- and Long-term National Plan for Science and Technology Development outlines 11 prioritised fields in research policies. These are:

- Energy,
- Water and mineral resources,
- Environment,

[90] Kroll et al. (2008: 170).

[91] Lang (2009), "Policy mixes to stimulate research".

[92] Lang (2009), "Main aims for research policy".

[93] Kroll et al. (2008: 219f.).

- Agriculture,
- Manufacturing Technologies,
- Transportation,
- Information Technology,
- Population and Health,
- Urbanisation,
- Public Security,
- Defence.

In addition to these prioritised fields, eight frontier technologies have been selected as priorities for funding: biotechnology, information technology, new materials and nanotechnology, advanced manufacturing technologies, advanced energy technologies, ocean technology, laser technology, and aeronautics and astronautics.

6.3 Policies and Programmes for Coordinated Research in China

6.3.1 Introduction

This section shall give a more specific introduction into the way the policies and programmes are organized at the national level, especially as regards coordinating research. It looks at trends towards coordination at the federal level and whether even the notion of Critical Mass appears as a rationale for research policies and programmes at the federal level.

In China, "funding for public research is primarily co-ordinated at the central government level. This makes it possible for the government to address disparities in research resources among regions, co-ordinate research efforts and avoid unnecessary overlapping."[94] Regional disparities in China are wide because of the large and diversified territorial units which differ significantly in industrial composition, culture, natural, financial and human resources. Therefore one rationale for research policy is to support a coherent development of regions. There are some examples for such **regional coordination activities** are, in which regional governments, which are responsible for developing regional research policies and programmes, often cooperate with each other and form alliances to share resources.

However, at the current state of economic development policy rational is focused on domestic research and development. China faces a rapid technology catch-up process. Mathews and Cho (2000) break this development down into three fundamental stages. Networking (with foreign actors) fosters (affiliated) knowledge transfer and initializes (internal) learning (summing it up as Linkage, Leverage, and Learning). So **critical mass** is a determinant that should be created to advance **technology cycle catching-up**. Catching-up (especially leap-froging) policies are focused on strong national industrial policy (Japan, South-Korea), support of large companies (South Korea), university-driven technology clusters (Taiwan) and foreign direct investment policy (Singapore, Taiwan, Indonesia, Thailand) (Mathews/Cho 2000). China has the ability to combine all these strategies to a unique policy mix. One can conclude that this is an **Asian perspective on critical mass** and quite different from the CM understanding developed within ERA. However, this approach can be also regarded to show similarities to the objective of reaching "**self-sustained" dynamics"** in a field.

[94] OECD (2008: 444).

There are also a number of indications that the Chinese research and innovation policy is addressing further CM objectives, such as national/**societal challenges** (sending a Chinese to the moon) and **excellence**.
Excellence based policy depends mostly on concepts of high technology parks (HTPs) which support marketing and internationalization. Furthermore HTPs are an important industrial location of multinational subsidiaries and joint ventures. Every regional authority possesses a HTP (except Qinghai, Ningxia, Tibet). But there are also several problems because some HTPs are more like an industrial park with low dense networks and not as expected a high-tech facility with a high amount of inter-firm cooperation. Another way for reaching excellence was the identification of "universities of excellence" with the "project-211" in 1995. It aims at constructing 100 top universities and key disciplines to promote the development of higher education and enhance performance of science, technology and culture (ProInno Policy Trendchart 2010a). In his research about the Chinese-global university network system Hennemann (2008) identified a hierarchical level. He concluded that Chinese elite universities have a strong and increasingly dominant position to connect China to the global knowledge system. This result displays the impact of "project-211" to reach excellence.

6.3.2 Selected Initiatives and Programmes

6.3.2.1 The National Natural Science Foundation: Joint Funds

The National Natural Science Foundation of China itself offers several funding schemes (General Programme, Key Programme, Joint Fund). Especially the programmes of Joint Funds address the special issue to create critical mass. The joint funds are set up by NSFC in cooperation with relevant actors (government departments, local governments and industrial sectors) and they play a better guiding role to attract resources from different sectors to support basic research. There are different types of joint funds with different mission orientation: NSAF Joint Fund, Joint Fund of Astronomy, Joint Fund of Research on Major Science Facilities, NSFC-Guangdong Joint Fund and NSFC-Yunnan Joint Fund. In 2009, NSAF Joint Fund received 98 applications in total, and 35 of them were funded through panel evaluation. The total funding was 141 million Yuan (13.7 million Euro) with an average funding of 403.000 Yuan (39.091 Euro) per project (Nature National Science Foundation 2010b). In 2009 Joint Funding got 1688 applications with 281 approved projects and a total funding of 1.8008 Bio. Yuan (175 million Euro) (Nature National Science Foundation 2010a).
Compared to the ERA-Net scheme, this coordinates the initiatives of actors at the national, sub-national level and of the industry and is in this respect more similar to European Technology Platforms.
Evaluation and Impact: n.a.

6.3.2.2 Important Initiatives and Programmes

The policies and programmes analyzed in this section point out to the objective of reaching "self-sustained" dynamics" in a field, to addressing societal challenges and to reach excellence.
The **National High-tech R&D Programme** (called 863-programme) was founded in 1986 and implemented during three Five-Year plans. Due to limited science and technology capabilities this programme is to boost innovation capacity in high-tech sectors, particularly in strategic fields (with leap-froging development in key areas). Key projects are guided by pooling resources to address significant high-tech issues. Priority projects address frontier exploration research and as in respect applied research. All projects undergo peer review prior to funding in guidance by the

Ministry of Science and Technology which is responsible for the organization and administration (Ministry of Science and Technology 2010c; ProInno Policy Trendchart 2010e).
Initiated in 1982 the **Key Technologies R&D Programme** is the first Chinese S&T programme. This programme focuses on promoting technical upgrading and restructuring of industries. It also aims to cultivate an elite group involved in key technology R&D and to establish a number of internationally recognized technical innovation clusters. The promotion of industry-university-research (institutes) is an objective to bring the role of enterprises into full play (Ministry of Science and Technology 2010a).
In June 1997 the creation of the **National Basic Research Programme** (also called 973-programme) by the Ministry of Science and Technology was a fundamental step for promoting basic research. It organizes and implements key projects to meet Chinese strategic needs. Thereby its aim is to mobilize (and create) scientific talents in conducting innovative research formerly agriculture, energy, information, resources and environment, population and health, materials. Two years after project implementation a mid-term-evaluation decides about ongoing funding and research topic. The overall budget in the six year period (1998-2004) was 4.330 Billion Yuan (420 million Euro) (Ministry of Science and Technology 2010b; ProInno Policy Trendchart 2010d).

Programme	Subject
863: National High-Tech R&D Programme	IT, energy, resources and environment, advanced materials, biotechnology and agricultural technology
Key Technologies R&D Programme	R&D in agriculture processing and biotechnology, key manufacturing technologies, IT and high-tech industries, environment, traditional Chinese medicine, and social development
973: National Basic Research Programme	Basic and applied research in energy, agriculture, information, environment, population, health, materials and social development
Nanotechnology Basic Research Programme	Material Science and Nanotechnology
Knowledge Innovation Programme	Information, Biology, Advanced Materials, Manufacturing, New Energy Sources, Space and Oceanography, Environment and Ecology

Table 11: Overview on Chinese Research policy programmes

Sources: http://www.most.gov.cn/eng/programmemes1/index.htm; http://www.nsfc.gov.cn/english/07fd/06.html; http://proinno.intrasoft.be/index.cfm?fuseaction=wiw.measures&page=list&CO=83

In March 2002 the **Nanotechnology Basic Research Programme** has been initiated and funded by the National Natural Science Foundation of China. The aim of the programme is to explore basic theory, develop new research method with experimental technologies, and to promote interdisciplinary study. In future direction Nanotechnology is expected to have transforming and upgrading implications for mature technologies (ProInno Policy Trendchart 2010c).Till 2014 there will be a US$ 2.6 trillion market and as estimated 15 % of manufacturing output will be influenced by nanotechnology (Applebaum/Parker 2008: 320). So China is investing heavily on nanotechnology like the other developed countries (EU, USA, Japan), because there is a first-mover advantage through innovation. The Chinese success is indicated by a dramatic expended nanotechnology publication output (factor of 21) of the past decade (Applebaum/Parker 2008: 329). For a deeper understanding how China is able to become a nanotech leader, Applebaum and Parker (2008) provide a detailed overview.
With three phases the **Knowledge Innovation Programme** was inaugurated by the Chinese Academy of Sciences in 1998. It is expected to be completed in 2002. The Knowledge Innovation Programme provides funds to research institutes (affiliated with CAS) in order to allocate additional resources to the most promising institutes and research fields. It aims to improve

scientific performance and capabilities. The research themes of the Knowledge Innovation Programme include basic research, High-technology Research, Resource and Environment Technologies. The projects target basic research, exploratory research and industrial applications (ProInno Policy Trendchart 2010b).

6.3.2.3 Coordination initiatives for regional development

The 11th **Five-year Plan on Western Region Development** issued by the National Development and Reform Commission and the Steering Group of Western Region Development in the State Council in March 2007 includes inter-regional coordination by e.g. encouraging mobility and research collaborations between researchers and R&D institutions in eastern and western regions.[95]

Regional S&T Infrastructure Sharing Service Platform: Set up in June 2006 by six provinces and cities in the Bohai Sea Area including Beijing, Tianjin, Hebei, Inner Mongolia, Shandong and Shanxi to integrate S&T resources and reduce duplicate investment.

University Industry Alliance in South-western China: Initiated in November 2007 by the Science and Technology Commissions in Chongqing, Chengdu, Sichuan, Guizhou, Yunnan and Tibet to facilitate university-industry collaboration in this region. "The alliance has the goal to set up research infrastructure and develop key technologies by coordinating resources in the south-western region."[96]

Compared to the ERA-Net scheme these initiatives coordinate also sub-level initiatives in order to reduce duplication and/or reach common objectives. However, they are thematically open, as their primary aim is not to improve research capacities, but to contribute to regional development.

Evaluation and Impact: N.a.

6.3.2.4 CHINEKA Programme

This programme is an Industrial cooperation program between Chinese and Spanish companies that was started in 2003. The main objective of this program is to support industrial technology development and technology transfer projects by companies of both countries. Funds for joint projects come from the respective national S&T programmes. China's TORCH Centre and Spain's CDTI (Centro para el Desarrollo Tecnológic Industrial) jointly provide the needed funds for approved projects. This Chinese-Spanish cooperative programme targets high-tech firms in the biotechnology, energy, construction, IT, and machinery sectors. TORCH and CDTI are jointly administering applications from both sides.

Compared to the ERA-Net scheme, this joint programme shows certain similarities. There are no thematic guidelines except for the high-tech orientation. Compared to their respective national budgets for S&T, the budget for CHINEKA is relatively small. However, it aims at contributing to socio-technological challenges in terms of creating new process and products as well as gaining access to new markets.

Evaluation and impact: Initiated in December 2003, the memorandum of understanding was signed between TORCH and CDTI. The first CHINEKA Project was certified in April 2006. By May 2008 7 joint projects have been approved mobilizing more than 20 Million Euros (66 % in Spain and 34 % in China).[97]

[95] Lang (2009), "(Regional) Research policies and programmes" and "Main challenges for research policies"

[96] Lang (2009), "(Regional) Research policies and programmes".

[97] http://proinno.intrasoft.be/index.cfm?fuseaction=wiw.measures&page=detail&id=9493&CO=83

7 Conclusions

The comparison of the general trends of coordinated research programmes in the BRICs and the US showed several **similarities** with the EU in terms of programme orientation, steering of research directions as well as spending priorities. In terms of thematic orientation all countries have their focal points, mainly in the life sciences. Another dominant angle is the focus on key technologies, in particular nanoscience.

However, as stated above, it is difficult to compare these purely national programmes which often involve large amounts of money for a certain national mission with scheme being established and the amounts being raised in the EU ERA-Nets. Coordination in these research programmes mainly refers to the coordination among ministries (especially regarding cross cutting fields such as Biotechnology or Nanotechnology) or to the coordination efforts with sub-national units often without thematic focus, but with the intention to employ S&T advancement as a means to contribute to regional development and the economic catching up process.

Also all countries have their respective spending priorities. Coordination in this field mainly occurs by pure input steering. Different departments join their forces and set up "programme families". The research activities of Centre of Excellence, universities or private actors are ultimately geared towards these programmes since there are funds available.

A trend in most of the countries under analysis, pointed out to an orientation of academic excellence. Most of the identified programmes are geared towards raising the number of patents or articles in the respective field. The creation of basic knowledge or the formation of young researchers is at the heart of many of the programmes analyzed here. These patterns seem to be largely in line with the EU research support system.

On the other side, however, there are considerable **differences** between the support mechanisms elsewhere on the one hand and with the ERA-Nets on the other. Even though the comparability of the results of the analysis needs to be treated with caution, because the ERA-Net approach is a rather unique feature and in that form hardly to be found anywhere else, the amounts raised in the respective national contexts are much higher than the (virtual or common) pots under the ERA-Net scheme, which are shares of the participating countries' national budgets.

Also, another difference concerns the rationales for coordinating research policies. While it is true that many programmes tend to support only excellent research it is also true that in some countries coordinated research takes place to solve structural social challenges that have to do with the realities of developing countries. There are two emblematic cases in this regard: India and Brazil. Both of these countries devote considerable resources from various ministries and political levels to horizontal as well as thematic research activities that aim at alleviating poverty. Some of these activities result in actual growth industries (such as the generica sector) while other focus on the application of high-tech in precarious living situation (for example installing solar panels in rural areas for electrification).

Last but not least there are different forms of coordination of research. While Brazil and India show various forms of bottom-up approaches to include large groups of stakeholders in the design of governmental strategies, the Chinese case shows considerable top-down structures. The US also employs mechanisms to include the State level in certain research programmes, but focus in the first place on the bundling of defragmented resources at the national level. For the Brazilian case there also is empirical evidence that the inclusion of stakeholders from the local and state level contributes to the outcome of policies and the accountability of strategies.

With regard to the countries at stake it can be concluded that the **US** research and innovation policy clearly address the notion of generating critical mass – maybe not always in explicit terms. However, the mission-orientation of the US policy, **implies pooling a critical mass of resources. This is also true for the excellence orientation inherent in the US innovation policy.** For some efforts, there is also evidence available which documents success and impact. **More specifically, single initiatives follow specific objectives. The National Nanotechnology Initiative for example addresses likewise socio-economic and scientific challenges. But most of all, it aims at securing the US leading position in the field.** It can be assumed that a wider recapitulation of US research and innovation policies would arrive at the conclusion that all objectives related to critical mass play a role, i.e. also those relating to very young research fields or small/ unconnected research communities (Types 4 and 6, see Table 12).

In the case of **Brazil** it was shown that the goal of coordinated research is to expand, modernize and consolidate the national innovation system and to increase innovation efforts in areas of strategic national interest. Most programmes need to be seen in the light of the new Industrial, Technological and Foreign Trade Policy which aims to increase Brazilian value added in international trade. However, Brazil has not been successful in significantly increasing its R&D intensity over the recent years as the goal was to spend 1,5 % of GDP on R&D in 2010 (last available data for 2008 1,13 %).

Another factor that must not be underestimated is Brazil's effort to universalize the access to science and increase diffusion of technology for better living conditions. Science becomes important for social development. In this respect many policies are coordinated with the subnational level. The overall innovation strategy is the result of a long and very far reaching consulting process with societal stakeholders through local, regional and rational Conferences for Science and Technology. **In terms of CM-Analysis there is significant evidence for addressing the following objectives: Type 1 (socio-technological challenge), Type 4 (Securing competencies/ prospective) and Type 6 (to reach self sustained dynamics).**

Russia is an example of a rather centralized system. Even though the regions show a large degree of autonomy most of the policy decisions such as programmes' definitions are centralized in in Moscow. Research programmes in Russia are therefore mainly publicly founded from the federal budget. Priority areas of the development of science, technology and machinery range from safety and terrorism prevention, living systems, nanotechnology to aviation and space systems among others. The priority areas mark those fields which unite the largest amount of financial and human resources at national level. On the same and other topics, the Russian Federation is constantly developing effective international cooperation for the R&D sector.

In recent years, the Russian research and development areas experienced a noteworthy growth mainly thanks to institutional incentives. The current initiative is lead by the Governmental Commission on High Technologies and Innovations, established in 2007, whose role is to support the 2015 Comprehensive Programme by coordinating research policy. This governmental body illustrates the current overall priority that the Russian top leadership puts on a modernisation of the economy through R&D based innovation.

In the case of CM analysis, the Federal Target Programs (FTP) seems to be the most interesting programmes for coordinated (thematic) research. The programmes that are laid out in detail in Vol. 3 focus of **socio-technological challenges (Type 1)** and to a **lesser extend on scientific challenges (Type 2)** inasmuch as the programmes aim to create new knowledge and new research fields. This is especially true for the Nanoscientific programmes but also the Glonass-Satelite programme. All in all, the rather centralized Russian support system shows various signs of

transforming Russia into an innovative economy. **Therefore, much of the funding is also devoted at securing competencies in a prospective sense (Type 4).**

When summarizing the **Indian** case it needs to acknowledged that the current innovation policies and coordinated programmes have to address several issues at the same time: help solving societal challenges (e.g. rural poverty), trying to gain knowledge in future technologies with high market potential (e.g. biotechnology or nanotechnology) and competing with world-class research facilities outside the country in the industrial countries. There is a need to catch up in traditional technological fields and adapt them to the Indian reality. Self-directed basic research should receive substantially increased support. There are clear signs for a widespread mission orientation. The reasons for this have to do with the country's deep societal challenges such as poverty, malnutrition and urbanization. At the same time India has a strong tendency to establish Centres of Excellence in various domains.

One of the most interesting aspects of the Indian innovation Programmes is the focus on poverty alleviating aspects. Many of the efforts of the countless agencies and departments is surely devoted to academic excellence and frontier research, however there are also various programmes that aim to contribute to improve the living conditions of millions of people living below the poverty line.

Given that India is a federal country, the central government needs to coordinate policy guidelines with the states. States and central government are involved in a negotiation process about the priorities and strategies. The public consultation process that renders at best a common vision of the future course of scientific issues for economic and social development is close to what in the EU is called joint programming. **In terms of CM orientation there is a strong tendency towards Excellence (Type 5) and trying to meet socio-technical challenges (Type 1).**

Regarding **China** it seems obvious that innovation policies are first and foremost geared towards economic growth. The current rapid growth performance in the last decade is primarily associated with low- and middle tech export-oriented industrialization. The policy rationale is focused on domestic R&D and as a result China faces a rapid technology catch-up process. In this case Critical Mass becomes a determinant that is necessary to advance catching-up in the technology cycle.

Coordinated research by the Chinese government concentrates on making resources available for mission- (technology) and excellence-orientated projects. Some of these technology fields generate strong impacts for the next technology generation like biotechnology, advanced materials and space technology for example. Especially space technology and sending a Chinese to the moon is one of the key projects. In contrast to the Mission Orientation Statement the policy for excellence is not exactly defined. Excellence based policy depends mostly on concepts of high technology parks (HTPs) and massively support the financial endowment of public research institutions.

In conclusion the role of the Chinese funding schemes in this framework is somewhat unclear and hard to define. **In a rather tentative manner the most likely types of CM that apply to the Chinese case would by Type 6 (Self-sustained dynamics) and Type 4 (Securing competencies prospective).However, there are also a number of indications that the other CM objectives, such as national/societal challenges (sending a Chinese to the moon) (Type 1) and excellence (Type 5) are addressed.**

	Socio-technological challenge	Scientific challeng	Securing competence/defensive	Securing competence/prospective	Excellence	Self-sustained dynamic

		e				s
US	x	x	x	(x)	x	(x)
Brazil	x	(x)		x		x
Russia	x	x		x		
India	x	(x)		(x)	x	
China	x	(x)		x	x	x

Table 12: Comparison of objectives related to Critical Mass in the US and BRIC

Overall Table 12 gives a rough overview of the research and innovation policies reviewed in this chapter. It lists the objectives, which have been identified in this study to be relevant for the European Research Area (ERA) and which presumably can best (or only) be achieved by pooling a critical mass of resources. In the country comparison synthesized in this chapter we have compared which of these ERA objectives is also (most) relevant for R&I policies in the US and BRIC countries. We have looked at the policies and programmes in these countries which are executed at the federal level in general, but we have put a particular focus on those initiatives, which try coordinate or pool a set of individual approaches.

We find that despite the decentralised character of the US political system, there are a number of policies and measures at the federal level which address more or less the whole set of objectives, although those objectives related to new or research fields or small and unconnected communities seem to be less important compared to addressing challenges and building up or defending excellence. The BRIC countries show a different picture, for the reasons of technological and economic catching-up processes as discussed throughout this chapter. They have more focused approaches. In all cases these approaches include socio-economic objectives to which R&D need to contribute. In Brazil and China policy coordination focuses also on empowering, i.e. to build up self-sustaining research communities and competences in certain fields, however, sometimes on inferior technological levels. Excellent, high-tech “islands” in India or China are also addressed by national policies. The case of Russia is paradigmatic for a centralized system for research funding which puts it line with China.

This comparison – although limited to desk research – could give an illustration of the role the notion of critical mass plays outside the EU. Even if rarely mentioned explicitly and never defined, critical mass or even more the objectives, which can be addressed by pooling a critical mass of resources, are a relevant issue everywhere. This kind of research is limited as it cannot systematically assess how well these countries perform in pooling critical mass. In another part of the project, we have approached this by analysing patent and publication output not only of European institutions, but also of institutions located in the US and the BRIC countries. This kind of analysis cannot causally link the observed output to certain policy measures, but it can illustrate the strengths of the countries and regions in different selected disciplines, i.e. it can show the level of excellence achieved by different research communities in worldwide comparison.

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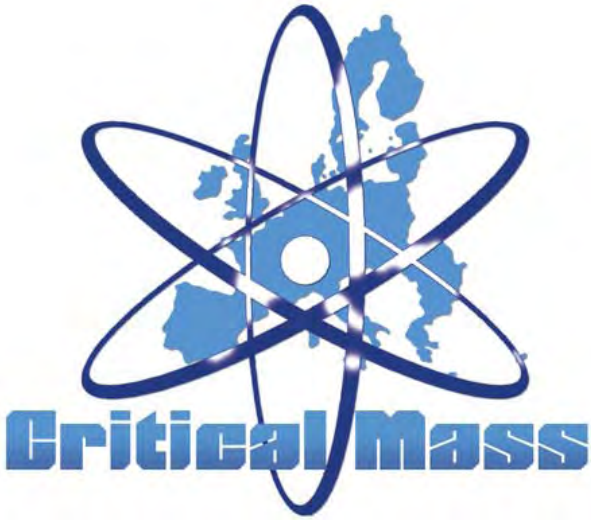
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Annex 4

Critical Mass measurement

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1 Exploring the use of external data sources as indicators for contextual factors

1.1 Methodology

Official statistics have been used as a second source of information, complementing and validating survey responses on contextual factors (see section 6.3 of the Final Report). Here, we report about the exploration of patent and publication data. Patent data have allowed ranking the EU innovation position vis-à-vis other world regions (USA, Japan, BRIC countries). Publication statistics have allowed doing the same for scientific excellence issues. The trend of publication and patents provide information about the growth rate of the sector and its degree of maturity. The next sections show the results of this analysis for the selected cases (see Table 1).

Table 1: Selected Cases for the Exploration of Publication and Patent Data

ERA-NET	Sciece/Technology Field	Publications	Patents
ERA SysBio	Systems Biology	X	
NEURON	Neuroscience/ Neurodegeneration	X	
BONUS	Marine Science/ Baltic Sea Research	X	
AirTN	Aeronautics Research		X
iMERA	Metrology		X
MARTEC	Shipping and Marine Engineering		X
EuroTransBio	Biotechnology		X
Manunet	Manufacturing Research		X

The major prerequisite for bibliometrics and technometrics is a good definition of the science/ technology field under consideration. The search strategy should allow to return a result which approximates best the publication or patent output of the field. (Of course, this requires also very good databases, to which we come back below.) The definition should comprise a set of search terms which is relevant for the whole field and/or a set of (sub-)classes of the databases' classification scheme which fits to the field.

For example, the field of systems biology is characterized by the convergence of life sciences ("classical" experimental ("wet lab") biology) with information technology & systems science ("dry lab" simulation, modeling…). Searching for the publications of the field poses a challenge, as it is an emerging field with contributions from biologists or from ICT research. Consequently, a search strategy using journal classifications (i.e. selecting relevant classes from a set of predefined (sub-) classes of the database employed) would need to include biology and ICT journals, as there is not (yet) a substantial stock of journals publishing systems biological results only. Without any further specification, this would mean that the search result would not only include system biology publications, but also publication from classical biology and from other fields of ICT research. A further specification of the search is possible by employing search terms. These search terms must be chosen in a way that they allow to identify system biological publications, i.e. the search string

must comprise terms, which typically appear in titles, abstracts or keywords of a publication (these three fields of publication databases are often the subject of the search). For systems biology such typical (combination of) terms are e.g. “simulation models of organisms” or “computational models of cell biological phenomenons” and similar.

To illustrate this example, applying our definition of systems biology yields a sample of more than 10,000 relevant publications for the field, while a search based on the simple search term “systems biology” yields with roughly 4,300 hits less than a half. A search strategy without any search terms in the publications of computational sciences and several life sciences returns more than 6 million relevant publications.

This example shows that the field definitions, which are key to the analysis, need careful thinking and knowledge about the fields. The knowledge about the different S&T fields is different: some are very well defined or definitions are easy to obtain, some are more fuzzy or in an early state of evolution. The eight fields we have explored for this study are different in these respects and therefore we have explored different methods in order to arrive at the field definitions.

Generally, owing to the characteristics of the databases employed for this study, we used the following search strategies: for bibliometrics we used a selection from a very rough classification scheme (of 27 classes) for scientific areas in combination with search terms which are constituent elements of publications of the scientific area under consideration; whereas for patents we used selection from a very fine classification scheme, which – once obtained – can be assumed to be an exhaustively precise definition of the field.

More in detail we have arrived at the search strategies using the following routes:

- Replication or adaptation of search strategies employed in earlier studies for: BONUS (from Snoeijs et al. 2008), ERA SysBio (from Reiss/Diekmann 2005), Manunet (from Dorffmeister et al. 2008);
- Identification of definitions for straightforward cases (e.g. unambiguous relation of the field to (sub-)classes of the existing classification schemes, and clearly identifiable search terms from publications or ERA-NET field descriptions) for: NEURON, AirTN, IMERA, and MARTEC;
- Approaching the definition using the knowledge about the research performing actors of the field: e.g. by tracing the patent activities of the research actors of a field, one can compile a set of sub-classes, where these actors typically file their patent applications and thus build up the definition of the field. This approach has been explored for biotechnology (EuroTransBio);
- Additionally, for fields hard to trace, expert interviews can be used in order to identify and/or validate search strategies: *this approach has not been explored in this study*.

When performing publication and patent analyses, some further methodological issues should be paid attention to, such as the choice of the databases, the choice of the indicators, and similar. How we considered these issues is being briefly referred to in the next sections.

Bibliometric approaches portray the scientific efforts in producing new knowledge. Scientific publications are the manifestation of the knowledge production process and they indicate a transfer of knowledge from the researcher to the scientific community. Bibliometric research uses information compiled from academic texts, mainly journal articles, to construct measures that can be used to assess a number of important dimensions of academic work.
Two dimensions of publication data can be analysed. The first dimension is the quantity of publications published by a scientific entity. The underlying assumption is that the more papers are published, the higher is the scientific activity. The second dimension is the quality of a paper. Measures of quality principally involve consideration of the citation of academic publications, making the inference that the higher the level of citations received by a paper, the higher its quality. The journal in which an article appears can also give some insight into the quality of the article.
The analyses of the ERA-NETs are based on the database SCOPUS. This database was used, because of the broad coverage of scientific disciplines and countries in Europe and worldwide. The study of ERA-NETs focuses on the natural and engineering sciences, as well as medicine and life sciences. These fields of science are extensively covered in SCOPUS. One important advantage of SCOPUS is, in contrast to Web of Science, the better linkage of all author-names to their specific organisation. Especially in the early phase of the analysed period, Web of Science provides in some cases just the name of the first author's organisation. The consequence is a bias in favour of first authors, because although there were different authors of different organisations working on the paper, there is just one countable organisation.

There are different types of counting academic output. Complete counting gives all countries one count. Even if one country appears more than once, it is counted every time it appears. In the straight counting just the first author-country gets one count. Whole-count gives full credit to every author named on the paper and every entity is counted once. In contrast to the complete count-method, every country gets one count, no matter how often it appears in the list of countries (Gauffriau et al. 2008). The fractional counting-method gives one count to each publication, several authors or involved organisations get a fraction of it i.e. 1 is divided by the number of entities and every entity gets just a fraction, e.g. two authors of two organisations worked on a paper, it would be counted as on-half to each. The quantity of publications of the several ERA-NETS was collected by using the whole-count-method. Thus if one paper had several authors from different countries, every country got one count for its contribution. This counting method was chosen, because this method considers all authors and their contributions to a published paper. Another reason is the access to the database. This part of analysis was conducted with the online-version of SCOPUS. Using this kind of data access implies a restricted availability of counting methods, but also the latest data. In respect to this constrains the whole count-method was the optimal counting method for the quantity of publications.
To give credit to the diverse publication habits of the S&T fields explored in this study, we did not only search in journal publications, but also in books and proceedings. All publications were included in the result, where one (combination of) search term(s) appeared in the title, the abstract or the keywords.

The quality of the publications in the fields of system biology and neuroscience (see section 2 of this annex for results) was determined by the citations of papers of all organisations in these fields. To obtain valid citation data, citations in a three year time frame are considered, i.e. all

citations of a paper, which were given in the year of publication and the following two years, are counted. The analyses were conducted with a relational in-house database of SCOPUS. This enabled us to count the citations fractionally. Citations for papers of the publication years 2002 and 2007 were ascertained. Because of the three years time frame, 2007 was the most recent publication year we could analyse. Citation analyses of the publication year 2008 could not be provided, because in the in-house database the year 2010 is not yet fully covered. However a systematic analysis of citations could not be conducted with the online-version of SCOPUS. To identify changes in scientific leadership of the selected fields, we provide the results of a citation analysis of the (older) publication year 2002.

Further bibliometric measures of interest in the context of Critical Mass could be co-publications and publication credentials. Co-publishing (and similarly co-patenting) can generate data about pre-existing contacts of researchers vs. new ones (facilitated by EU programmes for research collaboration). The analysis of credentials to research funding (organisations or programmes) given in the preface or first footnote of publications is only at its beginning. Should a systematic analysis become possible, the references to specific programmes (such as ERA-NET) could be analysed and counted as direct output of the programme.

The effective protection of intellectual property is an important incentive and thus a necessary precondition for the investment in innovation activities (Aschhoff et al. 2007). One of the key indicators to measure the innovative outcome and performance of countries, regions or technological fields are patent applications (or patent grants).
The patent indicator is prevalent in the economic literature and has many advantages because it can be tracked over long periods of time while being disaggregated at a very low level. This means that it can easily be assigned to individual business units and is accurate and precise in determining the timing of innovation processes (Grupp 1997).
For the analysis, patent applications by the date of their worldwide first filing (priorities) were used. The reason is that each patent application can be suspected to include an underlying inventive step and that more recent data can be analyzed. A limitation on granted patents would lead to a mix of innovations from different years - also counting inventions that have potentially taken place a long time ago - meaning that the association between patents and innovation expenditures could no longer be established in some years. In addition, only patents which are maintained up to the grant would be considered. This however is not always the case, since not all patent applications are granted by the respective patent offices and also often a direct application of the patent is not sought of by the applicant (Frietsch 2007).

To identify the ERA-Nets in the patent data, the International Patent Classification (IPC) was employed. This classification was introduced to systematically order all patents worldwide. Patents are not directly connected with products, but distinguished primarily by their technical implications. The IPC is updated annually and revised every three years, to capture technological change more effectively. Existing data is adjusted to the current version of the IPC, so to speak, it is "classified backwards" (Frietsch 2007; World Intellectual Property Organization (WIPO) 2006).
The IPC is hierarchical and consists - in descending order - of sections, classes, sub-classes, main groups and subgroups. The respective hierarchical level corresponds to the number of digits of the encoding (World Intellectual Property Organization (WIPO) 2006). Subgroups usually have seven

digits; four digits correspond to the sub-classes. The patent applications of the ERA-Nets were marked by a combination of IPC sub-classes (four digits).

The data for the patent analysis were extracted from the 'EPO Worldwide Patent Statistical Database' (PATSTAT), which provides information about published patents collected from 81 patent authorities worldwide.
For each of the ERA-Nets, the annual sum of transnational patent applications in total and by each country was counted. Transnational patent applications, i.e. patent families with at least one EPO and one international (PCT) application, were used since they are best able to map international markets in adequate relations (Frietsch/Schmoch 2010).

To ensure a better international comparability of the data, patent and publication intensities are calculated in addition to the absolute numbers. The patent/publication intensity is defined as the total number of patent applications/publications per million employees in the respective country. Moreover, the European Research Area has been defined in this comparison as "EU-27+4" including Israel, Norway, Turkey, and Switzerland.

1.2 Summary of Results

We find that publication and patent data are largely coherent with survey data, which mutually confirms the validity of these two data sources. It seems that survey data are easier to collect than performing publication and patent analysis to generate data, because the latter requires intensive study of the scientific and technological fields in order to define them properly. The results of the comparison are being displayed in Table 2.

Table 2: Comparison of Results from Survey and Publication / Patent Statistics

	SURVEY		PUBLICATION / PATENT STATISTICS	
	Evolution	Worldwide Position	Evolution	Worldwide Position
ERASysBio	Growing	n.a.	Growing	**Europe not leading**
NEURON	Growing	Europe not leading	Growing	Europe not leading
BONUS	Growing	Europe not leading	Growing	n.a.
AirTN	Mature	Europe leading	**Growing *(in Europe, in decline in US)***	Europe leading
iMERA	Growing	Europe leading	Growing	**Europe not leading *(Europe has caught up and is about to overturn the US in 2007)***
MARTEC	Growing	Europe leading	Growing	Europe leading
EUROTRANS-BIO	Growing	Europe not leading	Growing	Europe not leading
MANUNET	Growing	Europe leading	Growing	Europe leading

Note: Additional data gained by patents/publications is highlighted in green, data deviations are highlighted in red.

1.3 Example 1: Bibliometric statistics for Systems Biology (ERA-NET ERASysBio)

1.3.1 Techno-Scientific Conditions: Evolution of S&T area

The number of worldwide publications on Systems Biology rapidly increased from 187 in 2000 to 1,865 in 2010.

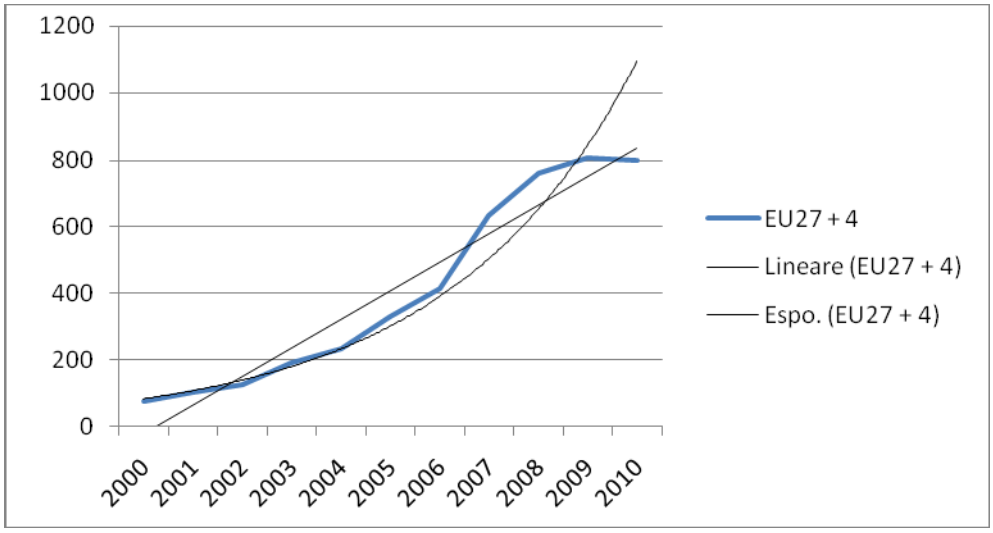
Table 3: Number of Publications in Systems Biology Worldwide and in Selected Regions, 2000-2010

Year	World	EU27+4		USA		BRIC	
2000	187	76	41%	88	47%	10	5%
2001	233	104	45%	90	39%	16	7%
2002	332	126	38%	155	47%	25	8%
2003	424	191	45%	182	43%	34	8%
2004	552	232	42%	236	43%	35	6%
2005	819	330	40%	338	41%	69	8%
2006	976	415	43%	399	41%	91	9%
2007	1,448	634	44%	513	35%	143	10%
2008	1,548	762	49%	570	37%	151	10%
2009	1,784	808	45%	675	38%	217	12%
2010	1,865	802	43%	738	40%	275	15%

Source: Scopus

In Europe the number of publications increased rapidly in the past, but no significant changes were observable in recent years. Currently, European research in the Systems Biology field has left the emerging phase and entered a growth phase with only marginal improvements to come. One cannot yet say whether this current stable research activity represents already maturity of the field.

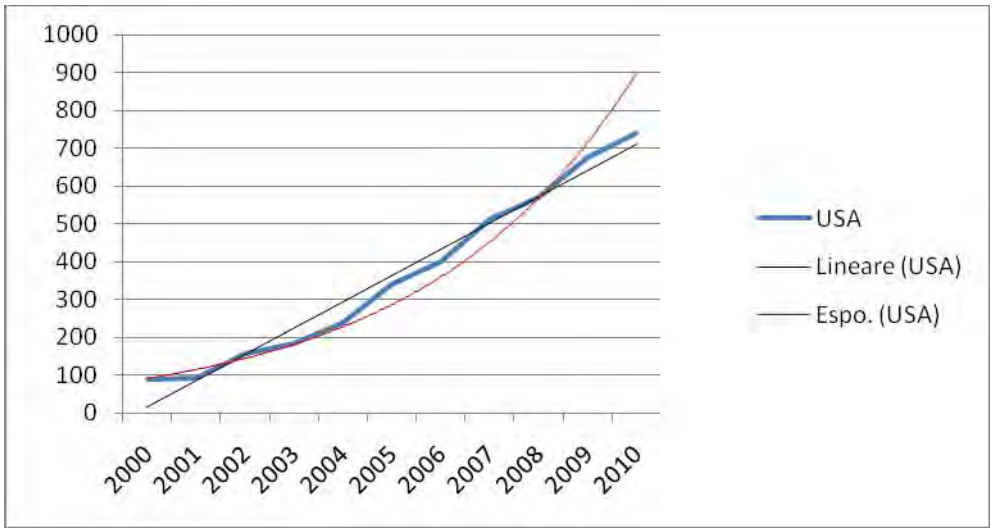
Figure 1: Evolution and Trend of Systems Biology Publications in Europe (EU27+4), 2000-2010



Source: Scopus

The growth in the U.S. publications is represented linear. This means that the U.S. publications have been consistently increasing without a stable phase in its activity, which contrasts with the European trend.

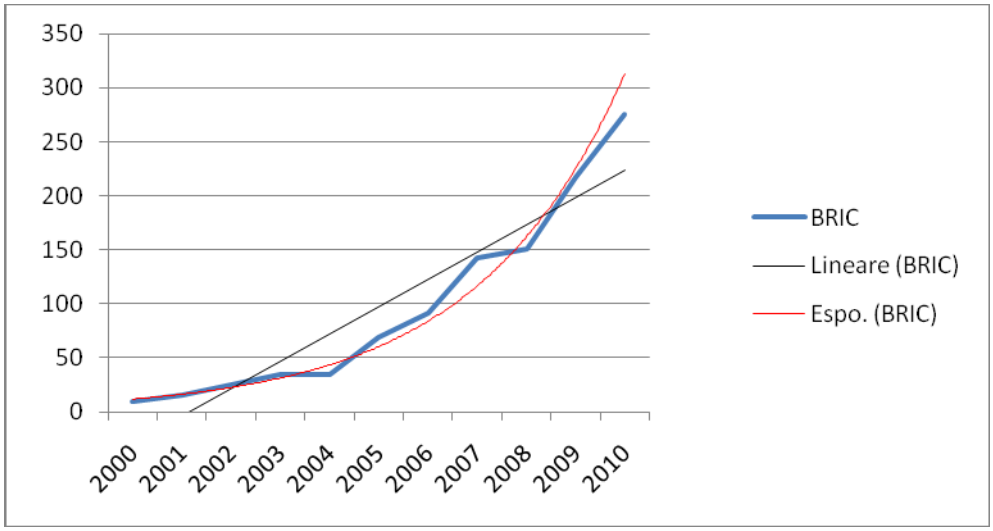
Figure 2: Evolution and Trend of Systems Biology Publications in the U.S., 2000-2010



Source: Scopus

The growth trend in the BRIC's publications is approximately exponential. In recent years BRIC went through a drastic increase in its research activity in comparison with Europe and the U.S.

Figure 3: Evolution and Trend of Systems Biology Publications in BRICs, 2000-2010

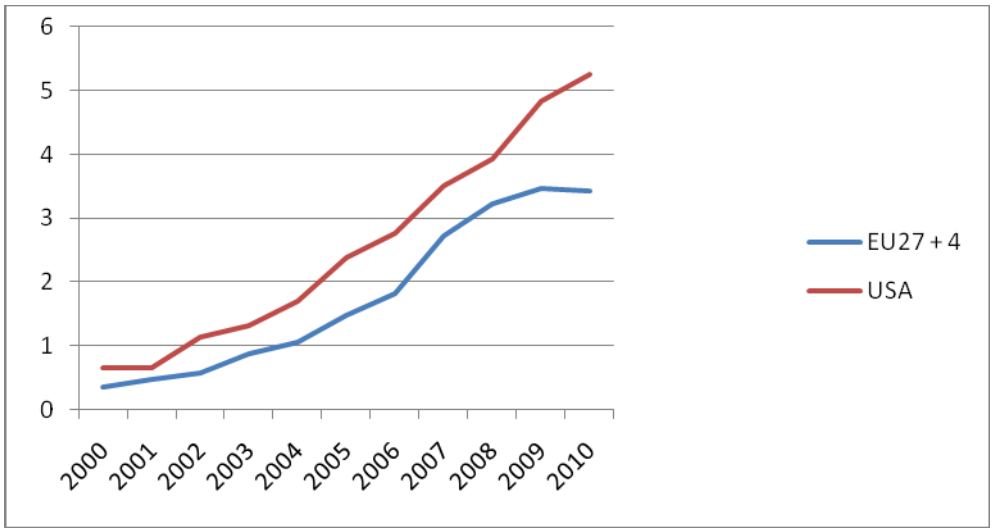


Source: Scopus

1.3.2 Geographic Conditions: Worldwide leading position in S&T area

The publication intensity chart suggests that the U.S. is leading Systems Biology research.

Figure 4: Comparison of Publication Intensities in Europe (EU27+4) and the U.S.



Source: Scopus

1.4 Example 2: Bibliometric statistics for Neuroscience/ Neurodegeneration (ERA-NET NEURON)

1.4.1 Techno-Scientific Conditions: Evolution of S&T area

The number of worldwide publications in the field of Neuroscience/ Neurodegeneration increased from 3,042 in the year 2000 to 6,552 in the year 2010. Publications doubled throughout the decade.

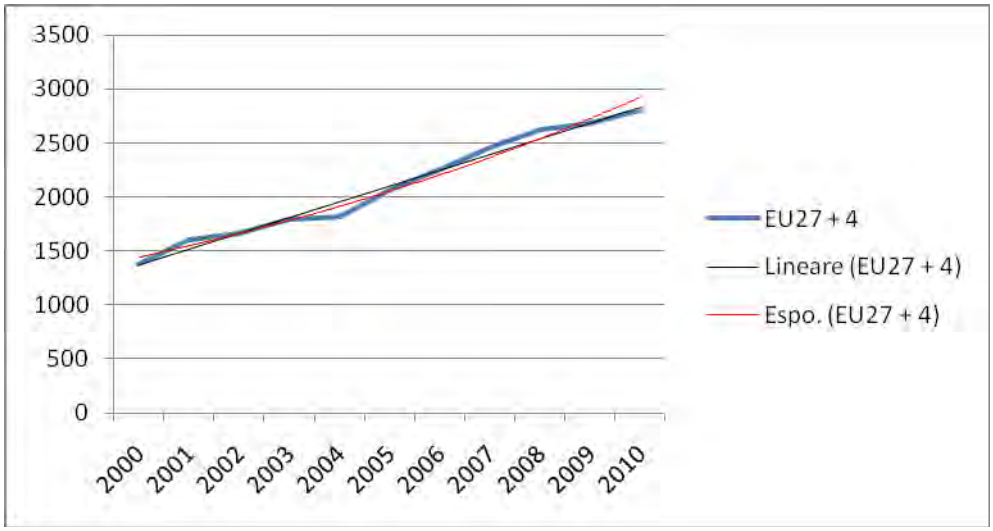
Table 4: Number of Publications in Neuroscience/Neurodegeneration Worldwide and in Selected Regions, 2000-2010

Year	World	EU27+4		USA		BRIC	
2000	3,042	1,381	45%	1,159	38%	99	3%
2001	3,494	1,605	46%	1,251	36%	112	3%
2002	3,653	1,667	46%	1,291	35%	150	4%
2003	3,789	1,794	47%	1,332	35%	225	6%
2004	4,080	1,818	45%	1,402	34%	206	5%
2005	4,621	2,068	45%	1,689	37%	357	8%
2006	5,059	2,252	45%	1,876	37%	372	7%
2007	5,648	2,461	44%	1,992	35%	444	8%
2008	5,935	2,621	44%	2,014	34%	536	9%
2009	6,091	2,683	44%	1,966	32%	564	9%
2010	6,552	2,801	43%	2,207	34%	690	11%

Source: Scopus

According to the graph below, the number of publications in Europe increased consistently, but the speed of the increase went down recently. This implies the European research phase in this field is only slightly growing.

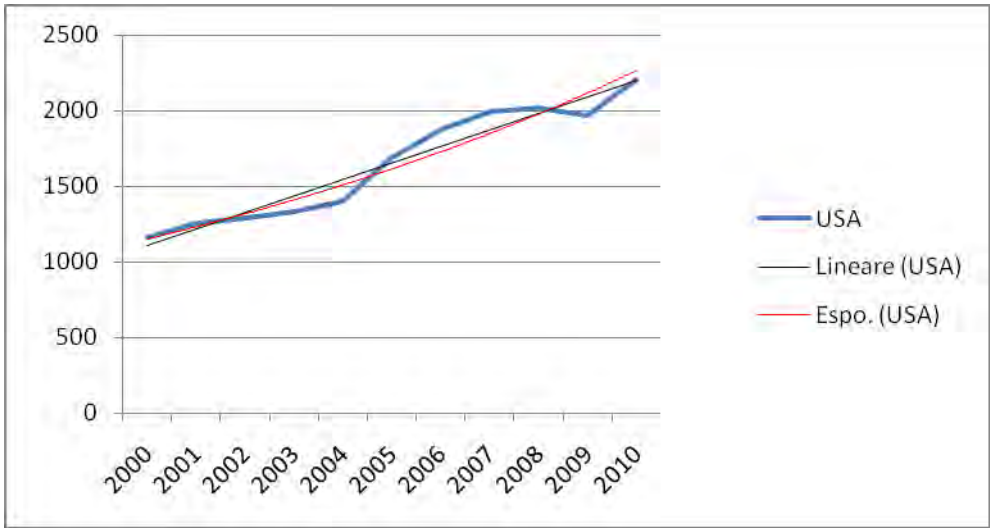
Figure 5: Evolution and Trend of Neuroscience/ Neurodegeneration Publications in Europe (EU27+4), 2000-2010



Source: Scopus

The U.S. has been recently experiencing a rapid growth in the number of publications as compared with the stable research phase of Europe.

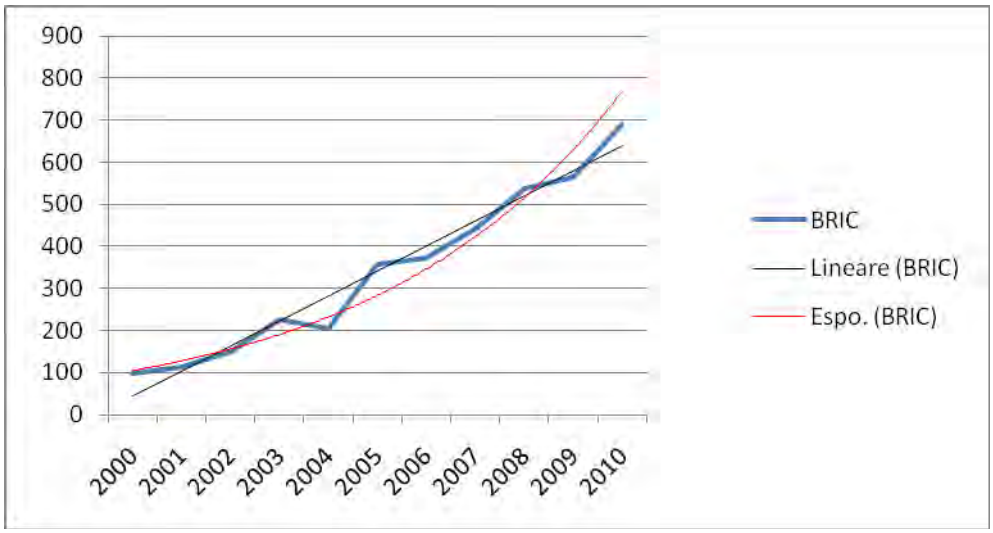
Figure 6: Evolution and Trend of Neuroscience/ Neurodegeneration Publications in the U.S., 2000-2010



Source: Scopus

The BRIC's research trend lies close to an exponential curve. The graph's slope and the general trend considered, the BRIC's research in this field grew at a higher rate of speed than Europe and the U.S.

Figure 7: Evolution and Trend of Neuroscience/ Neurodegeneration Publications in BRICs, 2000-2010

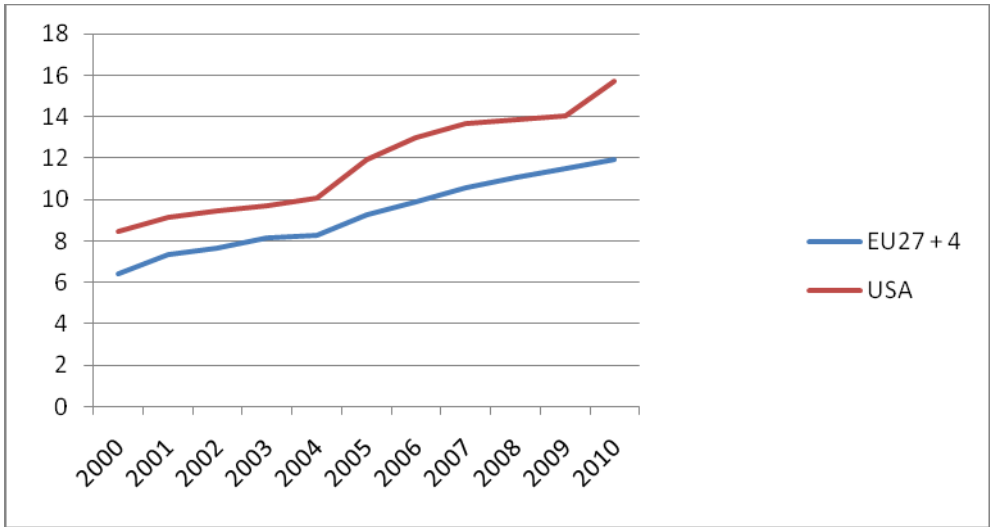


Source: Scopus

1.4.2 Geographic Conditions: Worldwide leading position in S&T area

The publication intensity graph demonstrates that the U.S. is leading research in the field of Neuroscience/ Neurodegeneration.

Figure 8: Comparison of Publication Intensities in Europe (EU27+4) and the U.S.



Source: Scopus

1.5 Example 3: Bibliometric statistics for Marine Science/ Baltic Sea Research (ERA-NET BONUS)

1.5.1 Techno-Scientific Conditions: Evolution of S&T area

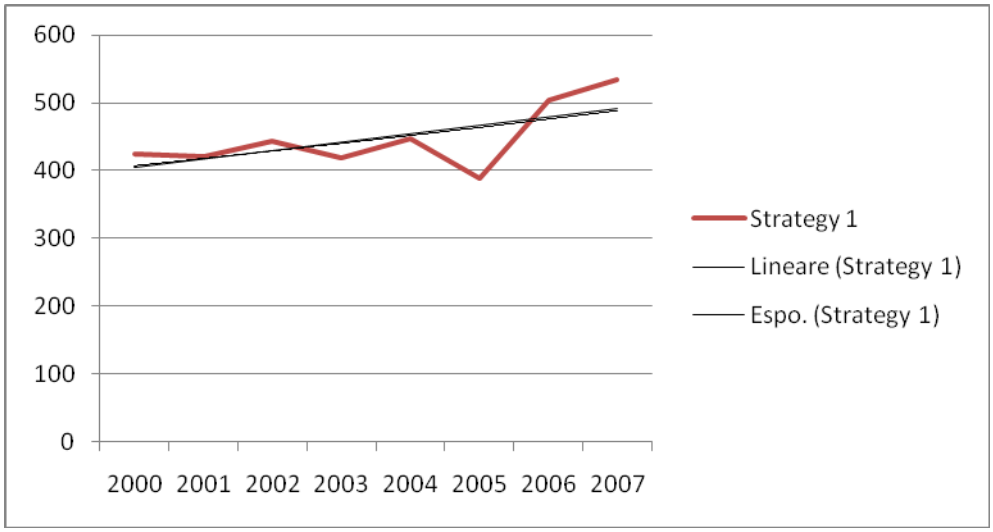
Table 5: Number of Publications in Marine Science/ Baltic Sea Research, 2000-2007

Year	Worldwide
2000	425
2001	421
2002	444
2003	418
2004	448
2005	389
2006	504
2007	535

Source: Scopus

The above table demonstrates that the number of publications in Marine Science/Baltic Sea Research increased from 425 in 2000 to 535 in 2007.
Based on the graph below, although there was a significant decrease in publications in the year 2005, the overall trend shows that the number of publications steadily increased throughout the decade.
Due to the low number of publications returned by Scopus for this field, we abstained from further analyses, as this field would require to include a set of other resources in order to be represented adequately, see Snoeijs et al (2008).

Figure 9: The Number of Publications in Marine Science/ Baltic Sea Research, 2000-2007



Source: Scopus

1.6 Example 4: Patent statistics for Aeronautics Research (ERA-NET AirTN)

1.6.1 Techno-Scientific Conditions: Evolution of S&T area

Table 6: Number of Patents in Aeronautics Research Worldwide and in Selected Regions, 1990-2007

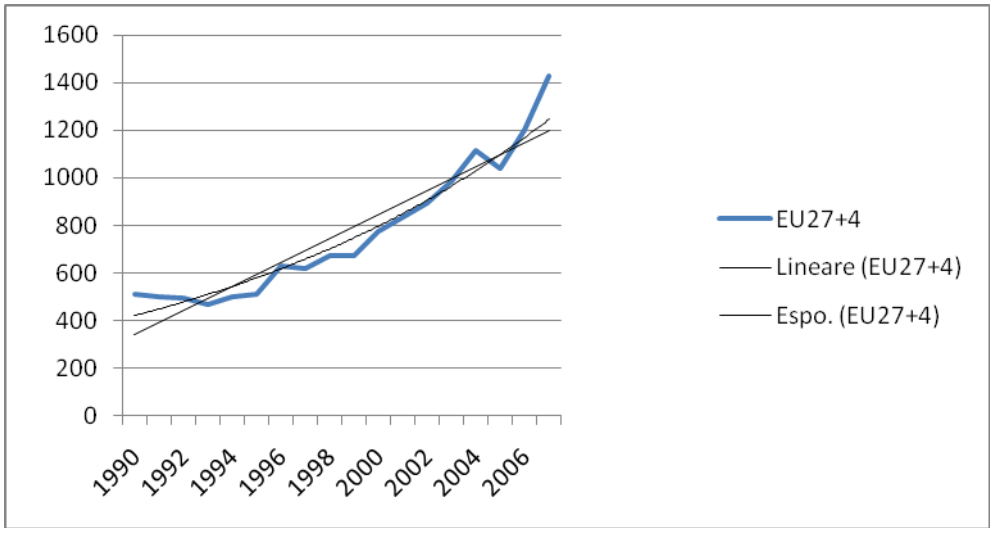
Year	World	EU27 + 4		USA		BRIC	
1990	1,019	513	50%	360	35%	0	0%
1991	1,005	498	50%	383	38%	7	1%
1992	955	494	52%	321	34%	30	3%
1993	934	466	50%	383	41%	8	1%
1994	1,002	501	50%	379	38%	22	2%
1995	1,044	513	49%	403	39%	19	2%
1996	1,210	629	52%	455	38%	34	3%
1997	1,336	618	46%	502	38%	18	1%
1998	1,404	674	48%	500	36%	22	2%
1999	1,530	672	44%	608	40%	39	3%
2000	1,735	775	45%	707	41%	36	2%
2001	1,877	832	44%	700	37%	20	1%
2002	1,902	894	47%	751	39%	26	1%
2003	2,068	983	48%	778	38%	42	2%
2004	2,165	1,116	52%	822	38%	34	2%
2005	2,154	1,037	48%	846	39%	46	2%
2006	2,444	1,199	49%	974	40%	61	2%
2007	2,519	1,430	57%	748	30%	79	3%

Source: PATSTAT, Fraunhofer ISI

The number of worldwide patents in the field of Aeronautics research increased from 1,019 in the year 1990 to 2,519 in the year 2007. The number of patents more than doubled throughout the recent two decades.

The growth trend in European patents on Aeronautics research roughly resembles an exponential curve. This indicates that European research is in the phase where the field was already partly explored but with a lot of research going on and an increasing number of researchers/labs involved.

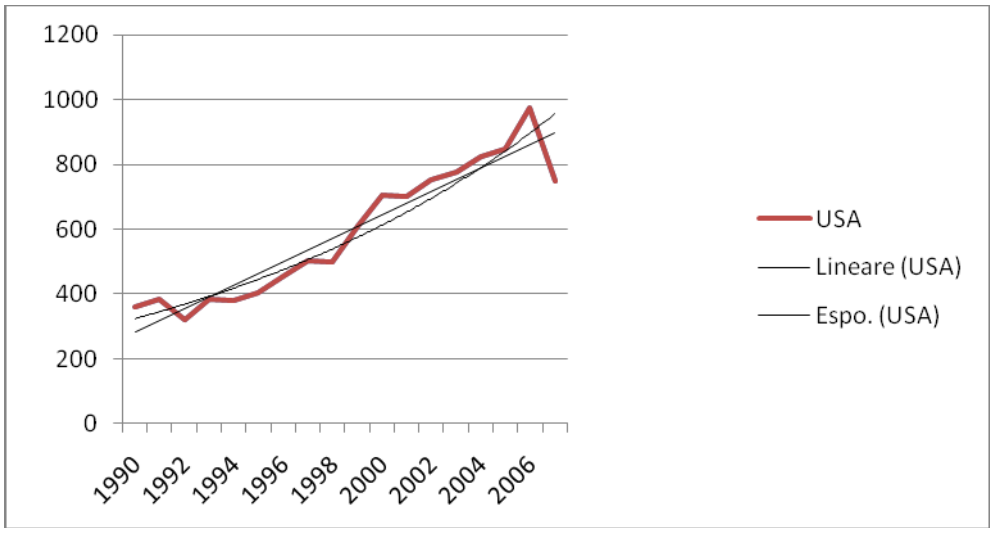
Figure 10: Evolution and Trend of Aeronautics Research Patents in Europe (EU27+4), 1990-2007



Source: PATSTAT, Fraunhofer ISI

In comparison with Europe, the U.S. recently experienced a sharp decrease in the number of patents.

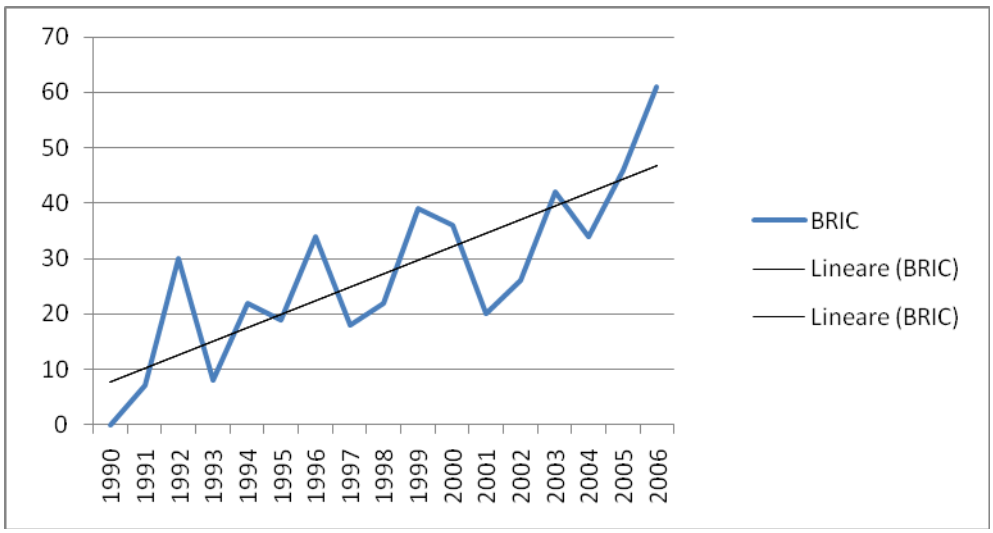
Figure 11: Evolution and Trend of Aeronautics Research Patents in the U.S., 1990-2007



Source: PATSTAT, Fraunhofer ISI

The number of patents filed by BRIC has been very volatile as compared with Europe and the U.S. However, research has been emerging and gradually developed.

Figure 12: Evolution and Trend of Aeronautics Research Patents in BRICs, 1990-2007

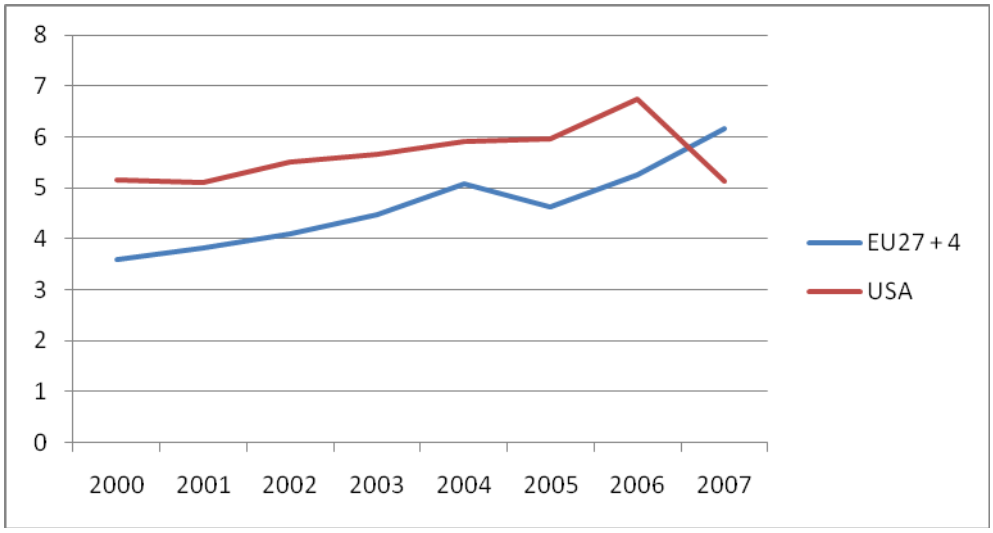


Source: PATSTAT, Fraunhofer ISI

1.6.2 Geographic Conditions: Worldwide leading position in S&T area

Based on patent intensity, the U.S. led research in the field of Aeronautic up to the year 2006. However, Europe started to lead research from the year 2007 on.

Figure 13: Comparison of Patent Intensities in Europe (EU27+4) and the U.S.



Source: PATSTAT, Fraunhofer ISI

1.7 Example 5: Patent statistics for Metrology (ERA-NET iMERA)

1.7.1 Techno-Scientific Conditions: Evolution of S&T area

Table 7: Number of Patents in Metrology Worldwide and in Selected Regions, 1990-2007

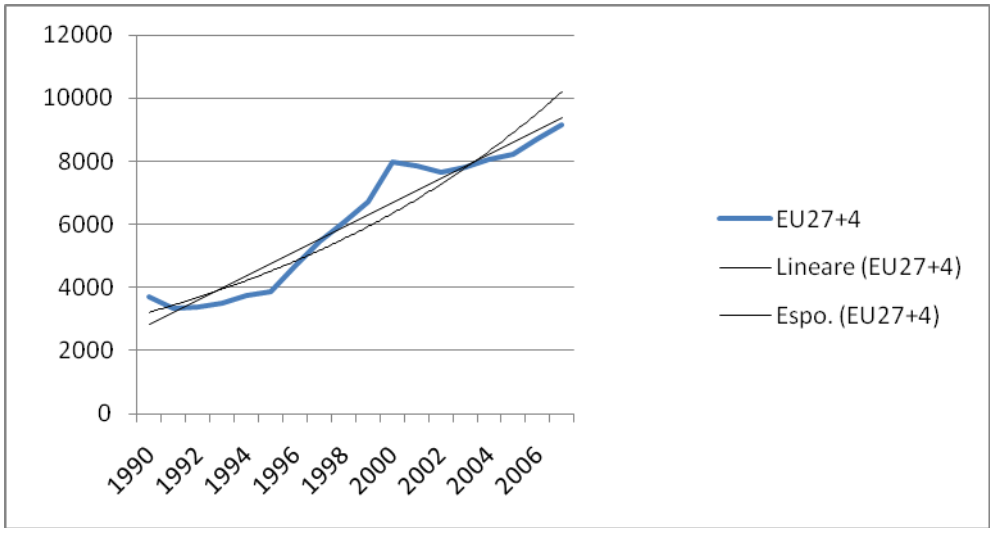
Year	World	EU27 + 4		USA		BRIC	
1990	8,272	3,718	45%	3,070	37%	9	0%
1991	7,686	3,328	43%	2,937	38%	17	0%
1992	7,448	3,368	45%	2,816	38%	31	0%
1993	7,682	3,497	46%	2,999	39%	39	1%
1994	8,152	3,732	46%	3,260	40%	59	1%
1995	8,925	3,882	43%	3,648	41%	51	1%
1996	10,323	4,685	45%	4,127	40%	78	1%
1997	11,986	5,436	45%	4,792	40%	84	1%
1998	13,325	6,074	46%	5,237	39%	136	1%
1999	15,449	6,734	44%	6,306	41%	158	1%
2000	18,163	7,986	44%	7,069	39%	176	1%
2001	18,512	7,857	42%	7,244	39%	199	1%
2002	17,828	7,637	43%	6,642	37%	282	2%
2003	18,514	7,832	42%	6,658	36%	297	2%
2004	18,377	8,069	44%	6,698	36%	313	2%
2005	19,165	8,241	43%	6,929	36%	411	2%
2006	19,812	8,719	44%	6,772	34%	530	3%
2007	19,277	9,174	48%	5,869	30%	551	3%

Source: PATSTAT, Fraunhofer ISI

The number of patents in the field of Metrology research increased from 8,272 in the year 1990 to 19,227 in the year 2007. The number more than doubled throughout the recent two decades.

The number of European patents in Metrology has been increasing steadily. European research is in the phase where the field was already partly explored but with a lot of research going on and an increasing number of researchers/labs involved.

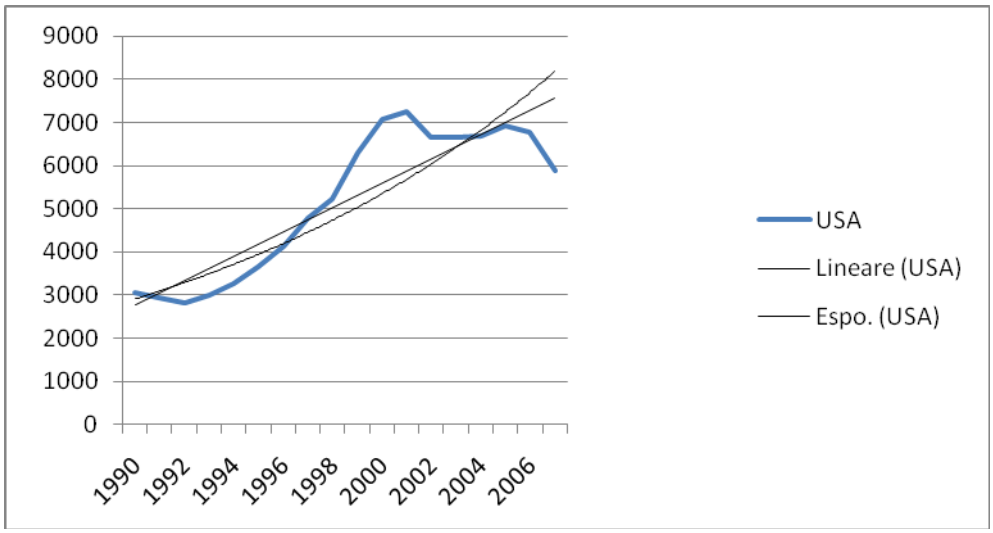
Figure 14: Evolution and Trend of Metrology Patents in Europe (EU27+4), 1990-2007



Source: PATSTAT, Fraunhofer ISI

As compared with European and BRIC research in this field, the U.S. research is in decline with fewer and fewer researchers/labs involved.

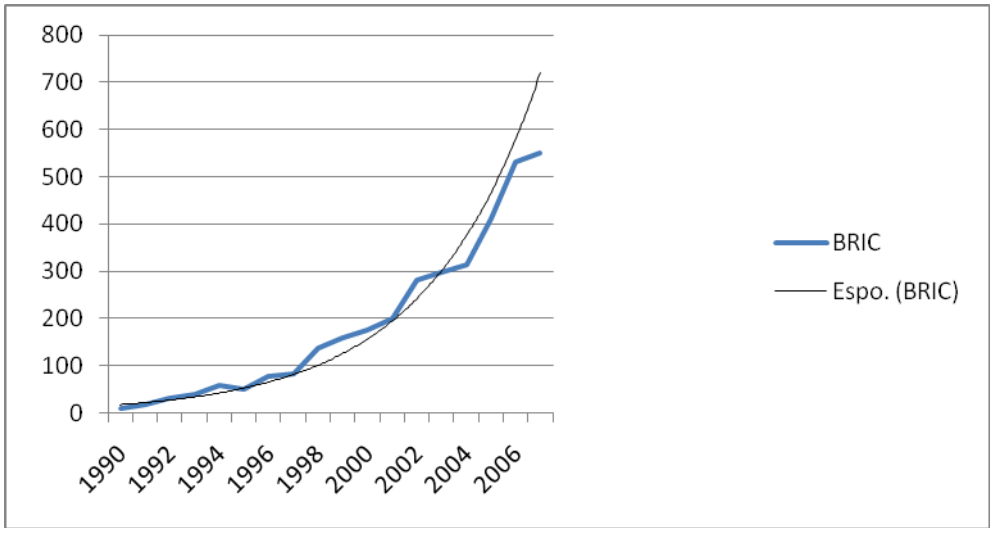
Figure 15: Evolution and Trend of Metrology Patents in the U.S., 1990-2007



Source: PATSTAT, Fraunhofer ISI

BRIC is experiencing drastic research advancement in the field of Metrology.

Figure 16: Evolution and Trend of Metrology Patents in BRICs, 1990-2007

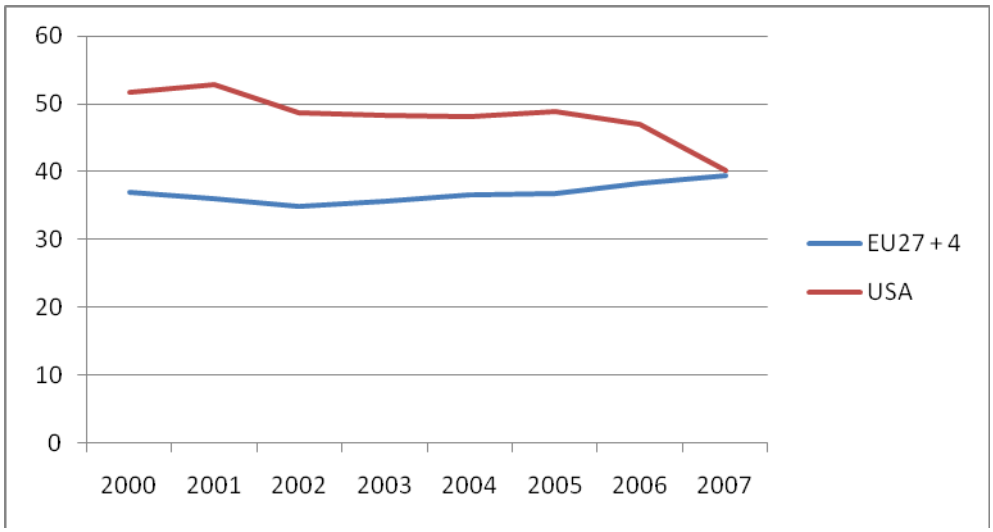


Source: PATSTAT, Fraunhofer ISI

1.7.2 Geographic Conditions: Worldwide leading position in S&T area

The U.S. was originally leading, but Europe started to overturn in the year 2007.

Figure 17: Comparison of Patent Intensities in Europe (EU27+4) and the U.S.



Source: PATSTAT, Fraunhofer ISI

1.8 Example 6: Patent statistics for Shipping and Marine Engineering (ERA-NET MARTEC)

1.8.1 Techno-Scientific Conditions: Evolution of S&T area

Table 8: Number of Patents in Marine Engineering Worldwide and in Selected Regions, 1990-2007

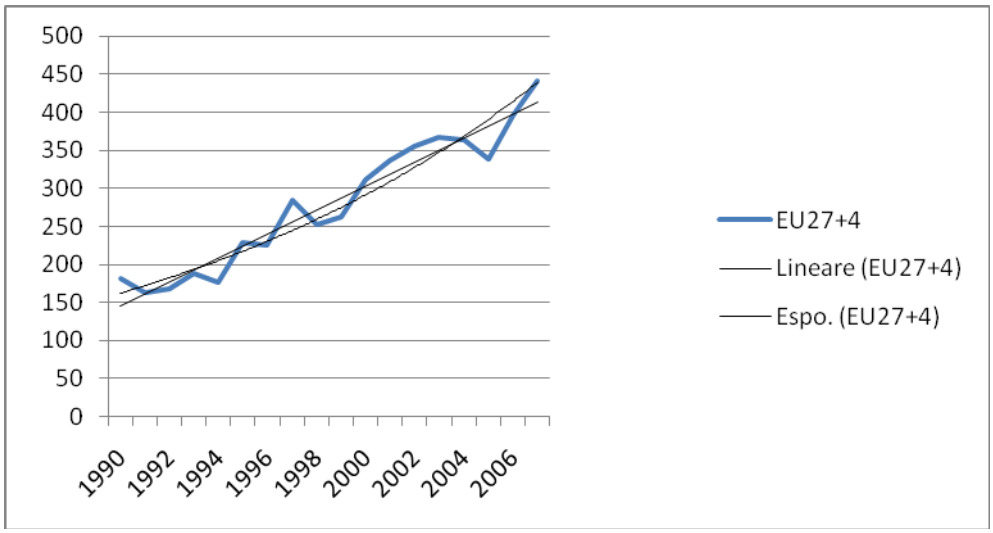
Year	World	EU27 + 4		USA		BRIC	
1990	309	181	59%	68	22%	4	1%
1991	265	163	62%	68	26%	1	0%
1992	248	168	68%	50	20%	0	0%
1993	307	188	61%	67	22%	8	3%
1994	272	176	65%	56	21%	7	3%
1995	355	228	64%	69	19%	3	1%
1996	380	226	59%	102	27%	8	2%
1997	449	285	63%	107	24%	7	2%
1998	431	253	59%	115	27%	8	2%
1999	444	263	59%	113	25%	16	4%
2000	503	311	62%	110	22%	9	2%
2001	591	337	57%	148	25%	9	2%
2002	637	355	56%	156	24%	20	3%
2003	641	367	57%	144	22%	20	3%
2004	627	363	58%	158	25%	28	4%
2005	610	338	55%	151	25%	16	3%
2006	692	396	57%	158	23%	31	4%
2007	735	441	60%	152	21%	25	3%

Source: PATSTAT, Fraunhofer ISI

The number of worldwide patents in Shipping and Marine Engineering increased from 309 in the year 1990 to 735 in the year 2007. The research advancement in this field is clearly observable from the increased number of patents.

The number of European patents in Shipping and Marine Engineering has been rapidly increasing. European research is in the phase where the field was already partly explored but with a lot of research going on and an increasing number of researchers/labs involved.

Figure 18: Evolution and Trend of Marine Engineering Patents in Europe (EU27+4), 1990-2007



Source: PATSTAT, Fraunhofer ISI

Compared with European research, the U.S. research phase is mature with only marginal improvement to come and a stable research activity.

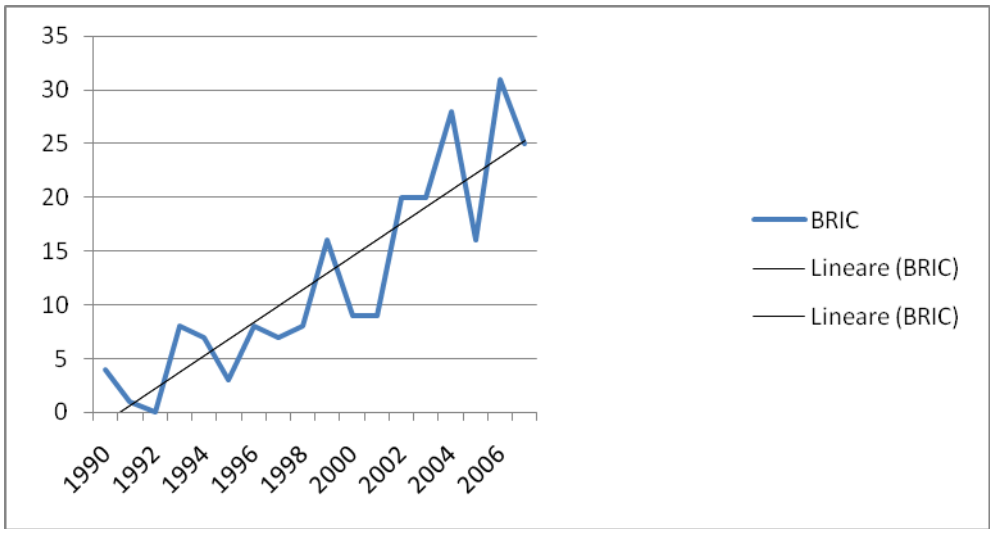
Figure 19: Evolution and Trend of Marine Engineering Patents in the U.S., 1990-2007



Source: PATSTAT, Fraunhofer ISI

BRIC's research is only emerging with a few researchers/labs exploring. The rapid growth in research is observable.

Figure 20: Evolution and Trend of Marine Engineering Patents in BRICs, 1990-2007

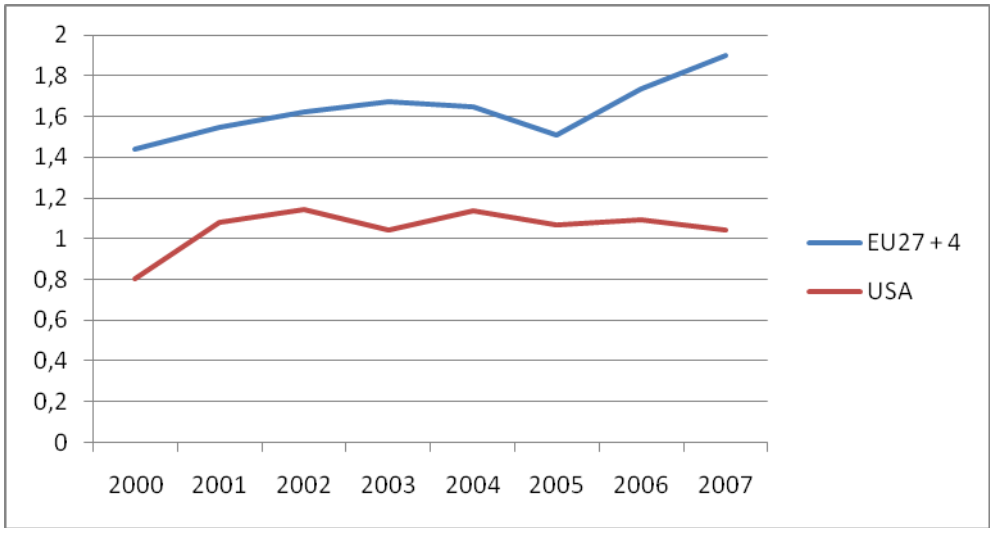


Source: PATSTAT, Fraunhofer ISI

1.8.2 Geographic Conditions: Worldwide leading position in S&T area

As demonstrated in the patent intensity graph, Europe is leading research in the field of Shipping and Marine Engineering

Figure 21: Comparison of Patent Intensities in Europe (EU27+4) and the U.S.



Source: PATSTAT, Fraunhofer ISI

1.9 Example 7: Patent statistics for Biotechnology (ERA-NET EuroTransBio)

1.9.1 Techno-Scientific Conditions: Evolution of S&T area

Table 9: Number of Patents in Biotechnology Worldwide and in Selected Regions, 1990-2007

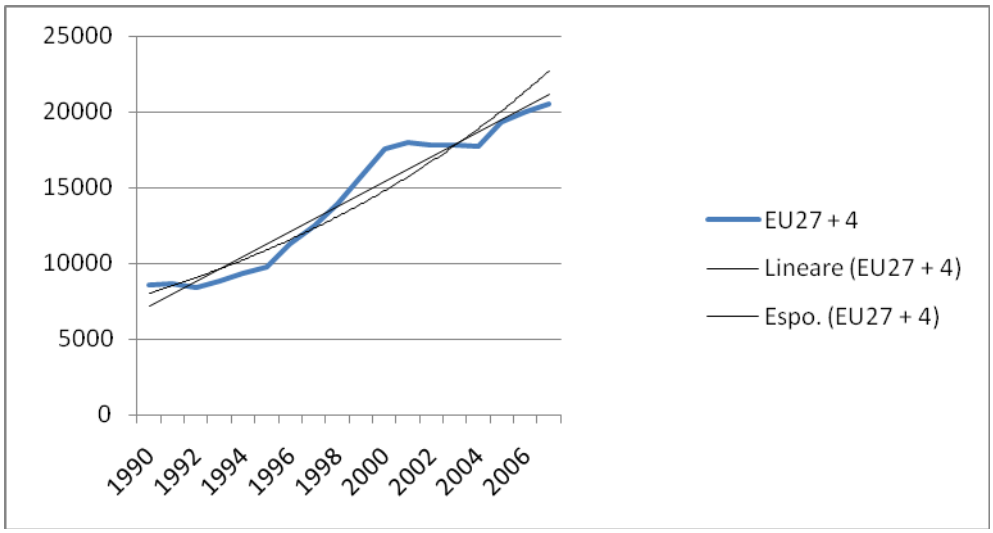
Year	World	EU27 + 4		USA		BRIC	
1990	20,957	8,587	41%	8,774	42%	27	0%
1991	20,798	8,639	42%	8,749	42%	43	0%
1992	20,113	8,378	42%	8,611	43%	93	0%
1993	20,993	8,820	42%	9,102	43%	136	1%
1994	21,437	9,359	44%	9,121	43%	173	1%
1995	23,846	9,718	41%	10,778	45%	174	1%
1996	26,968	11,261	42%	12,052	45%	249	1%
1997	30,459	12,456	41%	14,122	46%	337	1%
1998	33,011	13,891	42%	14,771	45%	551	2%
1999	38,007	15,726	41%	17,002	45%	954	3%
2000	43,564	17,523	40%	19,151	44%	1,714	4%
2001	43,639	18,002	41%	18,906	43%	1,063	2%
2002	44,218	17,772	40%	18,604	42%	1,435	3%
2003	44,626	17,777	40%	18,858	42%	1,678	4%
2004	43,142	17,718	41%	18,147	42%	1,545	4%
2005	47,606	19,338	41%	19,452	41%	2,027	4%
2006	48,817	20,021	41%	19,897	41%	2,413	5%
2007	47,714	20,520	43%	18,240	38%	2,481	5%

Source: PATSTAT, Fraunhofer ISI

The number of worldwide patents in Biotechnology increased from 20,957 in the year 1990 to 47,714 in the year 2007. The research advancement in this field is clearly observable from the increased number of patents.

The number of European patents in Biotechnology has been increasing steadily. European research is in the phase where the field was already partly explored but with a lot of research going on and an increasing number of researchers/labs involved.

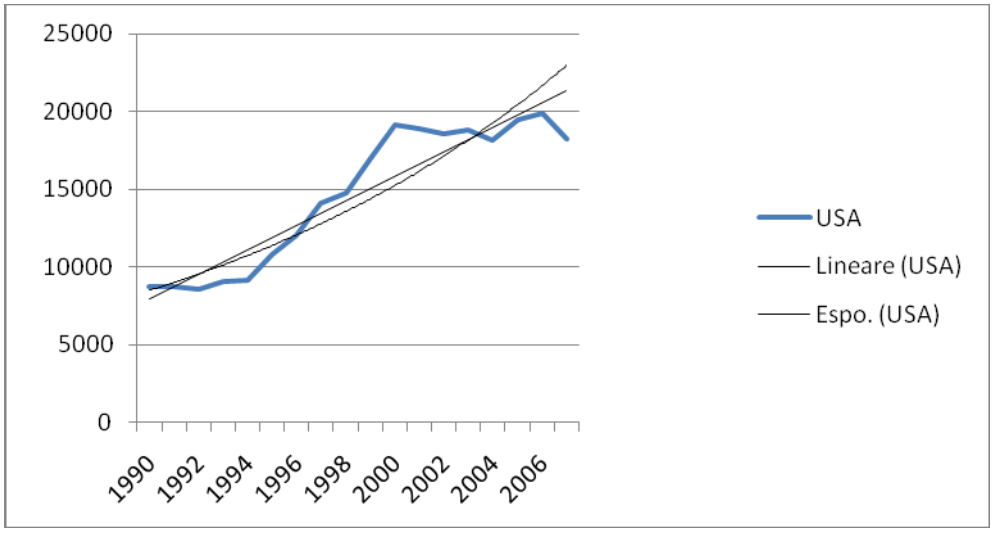
Figure 22: Evolution and Trend of Biotechnology Patents in Europe (EU27+4), 1990-2007



Source: PATSTAT, Fraunhofer ISI

In comparison with Europe, the U.S. research phase is mature with only marginal improvement to come and a stable research activity.

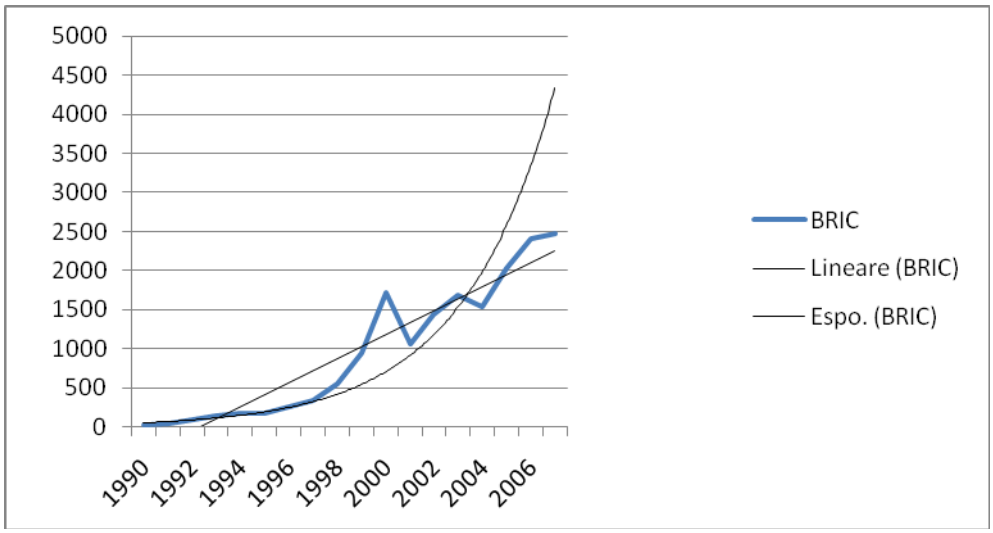
Figure 23: Evolution and Trend of Biotechnology Patents in the U.S., 1990-2007



Source: PATSTAT, Fraunhofer ISI

BRIC's research is only emerging with a few researchers/labs exploring.

Figure 24: Evolution and Trend of Biotechnology Patents in BRICs, 1990-2007

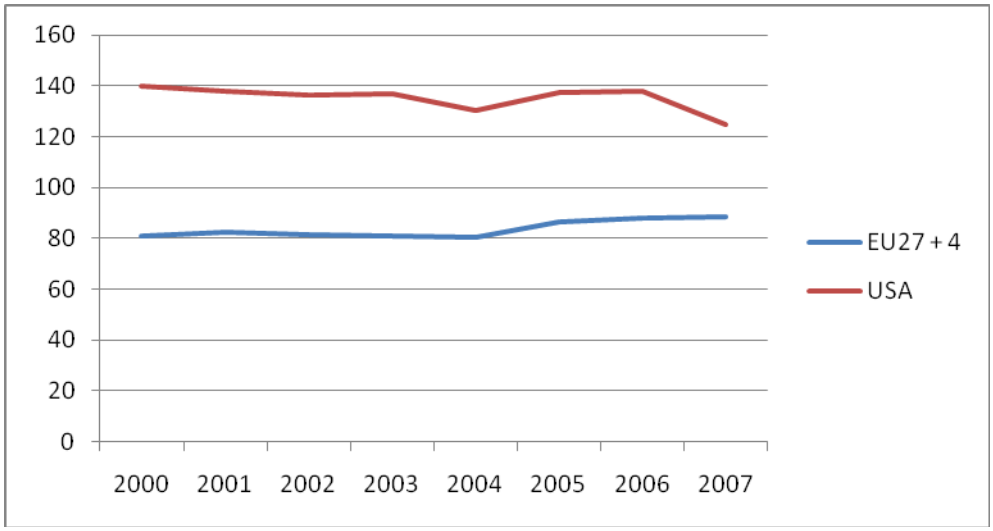


Source: PATSTAT, Fraunhofer ISI

1.9.2 Geographic Conditions: Worldwide leading position in S&T area

The U.S. is leading research in the field of Biotechnology.

Figure 25: Comparison of Patent intensities in Europe (EU27+4) and the U.S.



Source: PATSTAT, Fraunhofer ISI

1.10 Example 8: Patent statistics for Manufacturing Research (ERA-NET Manunet)

1.10.1 Techno-Scientific Conditions: Evolution of S&T area

Table 10: Number of Patents in Manufacturing Research Worldwide and in Selected Regions, 1990-2007

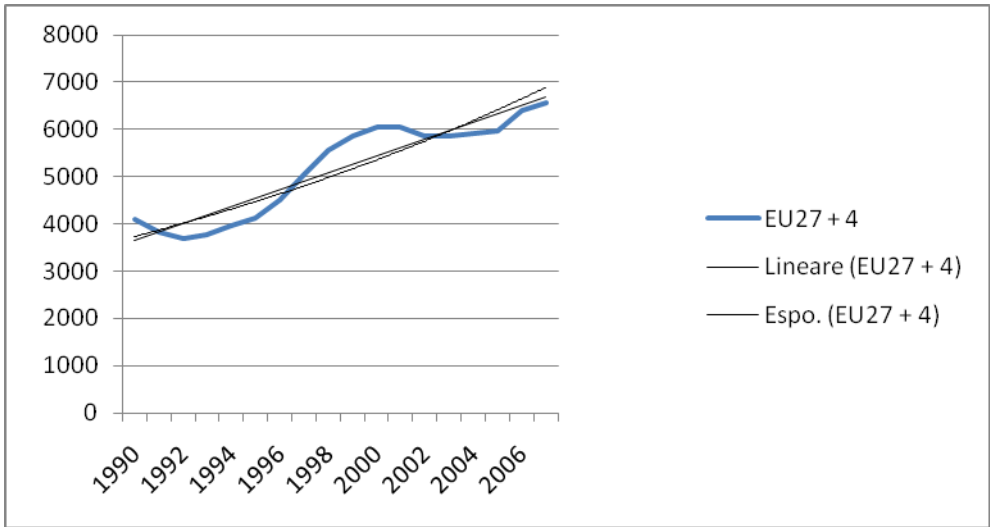
Year	World	EU27 + 4		USA		BRIC	
1990	7,529	4,108	55%	1,887	25%	12	0%
1991	7,056	3,838	54%	1,809	26%	21	0%
1992	6,772	3,688	54%	1,761	26%	29	0%
1993	6,880	3,774	55%	1,896	28%	41	1%
1994	7,052	3,956	56%	2,046	29%	24	0%
1995	7,619	4,115	54%	2,274	30%	52	1%
1996	8,215	4,508	55%	2,407	29%	50	1%
1997	9,069	5,049	56%	2,589	29%	58	1%
1998	9,766	5,550	57%	2,740	28%	88	1%
1999	10,615	5,853	55%	2,910	27%	149	1%
2000	11,372	6,062	53%	3,078	27%	103	1%
2001	11,171	6,038	54%	2,984	27%	145	1%
2002	11,059	5,870	53%	2,924	26%	164	1%
2003	11,047	5,857	53%	2,851	26%	202	2%
2004	10,896	5,924	54%	2,767	25%	185	2%
2005	11,094	5,976	54%	2,607	23%	261	2%
2006	11,627	6,391	55%	2,761	24%	297	3%
2007	11,740	6,566	56%	2,417	21%	361	3%

Source: PATSTAT, Fraunhofer ISI

The number of worldwide patents in Manufacturing Research increased from 7,529 in the year 1990 to 11,740 in the year 2007. The research advancement in this field is clearly observable from the increased number of patents.

European Manufacturing Research is on the edge of a growing phase, maybe already entering a mature phase with only marginal improvements to come and a stable research activity.

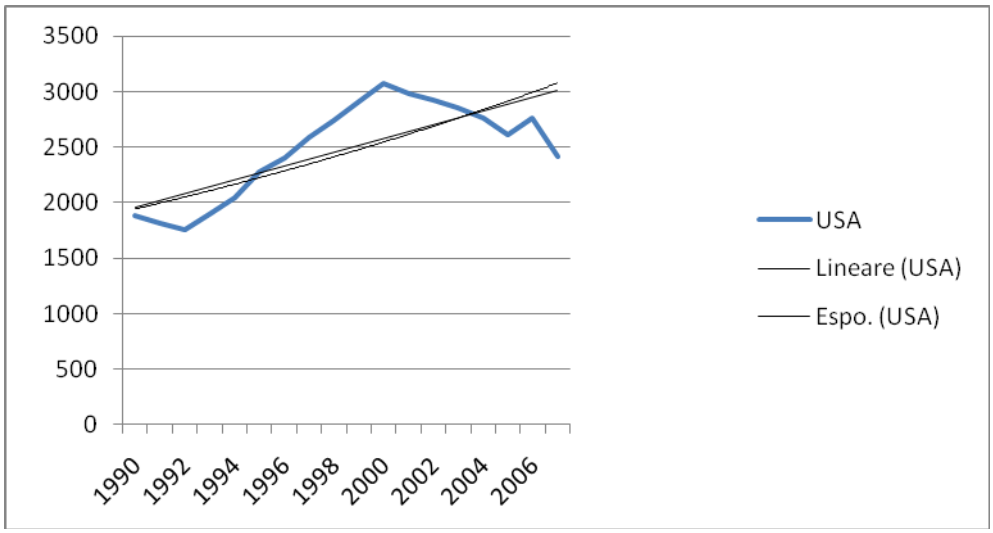
Figure 26: Evolution and Trend of Manufacturing Research Patents in Europe (EU27+4), 1990-2007



Source: PATSTAT, Fraunhofer ISI

The recent decrease in the number of patents shows that the U.S. research is currently in decline with less and less researchers/labs involved, contrary to Europe and BRIC.

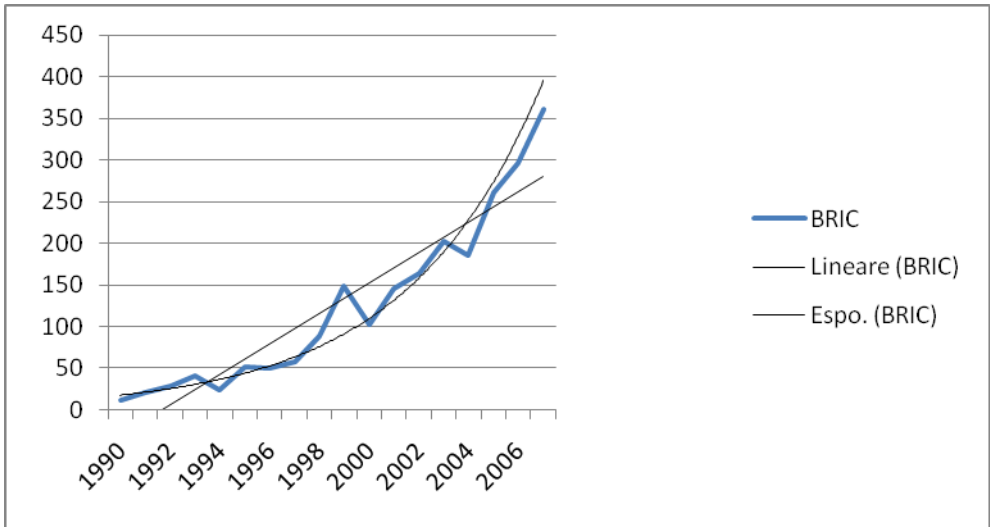
Figure 27: Evolution and Trend of Manufacturing Research Patents in the U.S., 1990-2007



Source: PATSTAT, Fraunhofer ISI

Throughout the recent decades BRIC has been experiencing rapid advancement in Manufacturing Research, as compared with Europe and the U.S.

Figure 28: Evolution and Trend of Manufacturing Research Patents in BRICs, 1990-2007

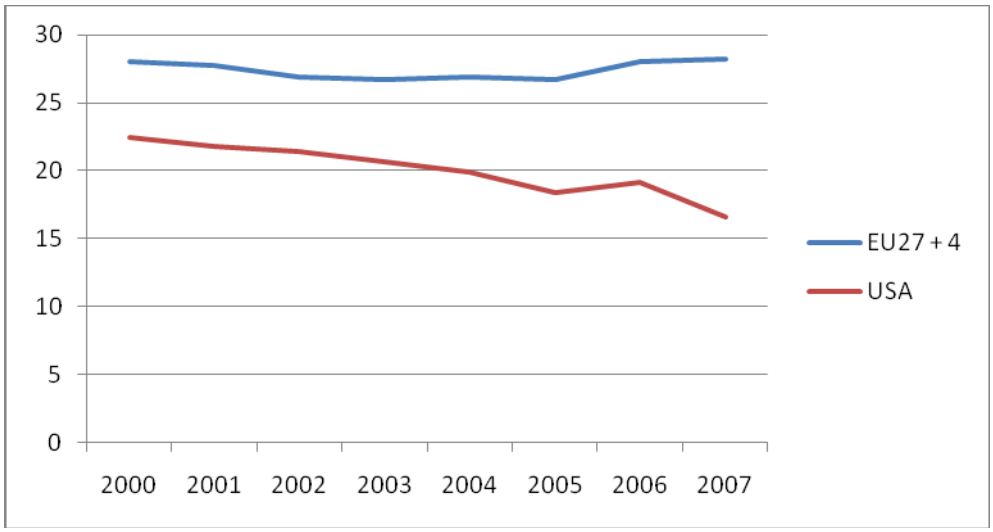


Source: PATSTAT, Fraunhofer ISI

1.10.2 Geographic Conditions: Worldwide leading position in S&T area

The patent intensity graph displays that Europe is leading Manufacturing Research.

Figure 29: Comparison of Patent Intensities in Europe (EU27+4) and the U.S.



Source: PATSTAT, Fraunhofer ISI

2 Exploring the use of external data sources as indicators for achievement

2.1 Example 1: Bibliometric statistics for Systems Biology (ERA-NET ERASysBio)

We have explored the excellence of ERASysBio beneficiaries in worldwide comparison using citations as a quality measure of publications (method has been described in section 1.1 above). The overall share of ERASysBio beneficiaries among the top 100 research institutions worldwide in 2007 was with 9% not very high (see Table 11), however this share has grown since 2002 (see Figure 30).

Table 11: Top 100 Research institutions in Systems Biology in 2007

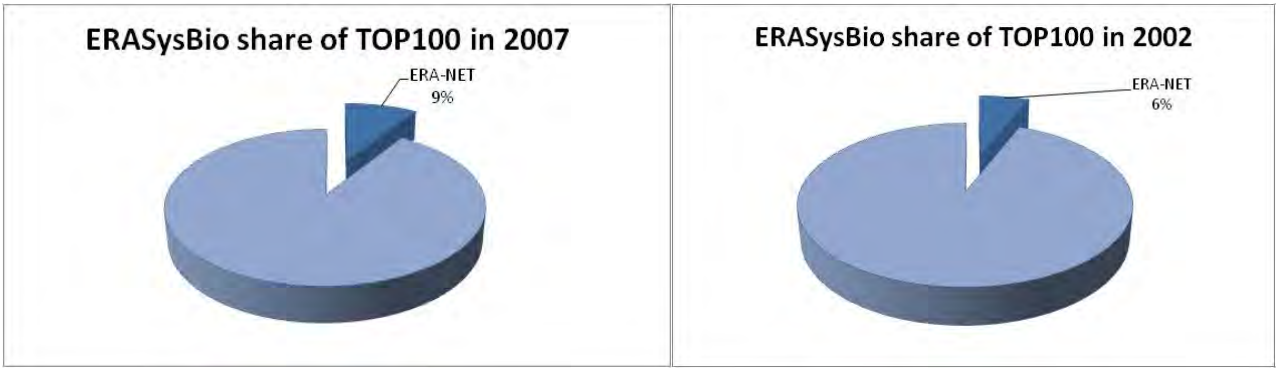
	Organization	City	Country	Citations
1	University of California	San Diego, CA	US	543,68
2	National Institute on Alcohol Abuse and Alcoholism	Bethesda, MD	US	437,00
3	Massachusetts Inst of Technology	Cambridge	US	310,01
4	ETH Zurich	Zurich	CH	283,93
5	Europ. Molecular Biology Laboratory	Heidelberg	DE	267,20
6	University of Toronto	Toronto, Ont.	CA	257,51
7	University of California	San Francisco, CA	US	246,38
8	Harvard Medical School	Boston, MA	US	230,55
9	University of Munich	Munich	DE	193,83
10	Dana-Farber Cancer Institute	Boston, MA	US	181,41
11	Johns Hopkins University School of Medicine	Baltimore, MD	US	172,44
12	Weizmann Institute of Science	Rehovot	IL	162,62
13	**University of Rome La Sapienza**	**Rome**	**IT**	**162,58**
14	University of Pennsylvania	Philadelphia, PA	US	161,03
15	University of California	Berkeley, CA	US	154,91
16	California Institute of Technology	Pasadena, CA	US	150,49
17	EPFL	Lausanne	CH	144,89
18	Institute for Systems Biology	Seattle, WA	US	142,91
19	Stanford University	Stanford, CA	US	139,20
20	University of Zurich	Zurich	CH	137,57
21	Imperial College	London	GB	131,69
22	**Harvard University**	**Cambridge, MA**	**US**	**131,45**
23	University of California	Los Angeles, CA	US	129,35
24	University of Michigan	Ann Arbor, MI	US	128,53
25	**University of Manchester**	**Manchester**	**GB**	**127,59**
26	University of California	Irvine, CA	US	127,49
27	**University of Oxford**	**Oxford**	**GB**	**125,97**
28	University of California	Davis, CA	US	124,55
29	University College London	London	GB	122,90
30	Pennsylvania State University	University Park, PA	US	122,59
31	SRI International	Menlo Park, CA	US	122,11
32	University of Cambridge	Cambridge	GB	117,06

33	Duke University	Durham, NC	US	115,40
34	Yale University	New Haven, CT	US	114,67
35	Gordon Life Science Institute	San Diego, CA	US	113,00
36	University of North Carolina	Chapel Hill, NC	US	108,04
37	Johns Hopkins University	Baltimore, MD	US	107,87
38	Columbia University	New York, NY	US	107,00
39	Indiana University	Bloomington, IN 47405	US	105,65
40	Shanghai Jiaotong University	Shanghai	CN	101,67
41	UniversitÃ¤t Bielefeld	Bielefeld	DE	101,00
42	Mount Sinai Hospital	Toronto, Ont.	CA	97,10
43	Max Planck Institute for Molecular Genetics	Berlin	DE	96,61
44	Max Planck Institute for Polymer Research	Mainz	DE	95,00
45	Boston University	Boston, MA	US	94,89
46	J. W. Goethe-UniversitÃ¤t Frankfurt	Frankfurt/Main	DE	94,50
47	Lawrence Berkeley National Laboratory	Berkeley, CA	US	94,44
48	Academic Medical Center	Amsterdam	NL	93,91
49	University of Chicago	Chicago, IL	US	93,38
50	Univ of Tokyo	Tokyo	JP	92,47
51	University of Queensland	Brisbane, QLD	AU	91,83
52	University of Bologna	Bologna	IT	91,08
53	University of Calgary	Calgary, Alta.	CA	90,50
54	Washington University	St. Louis, MO	US	89,23
55	**Technical Univ of Denmark**	**Lyngby**	**DK**	**89,07**
56	McGill University	Montreal, Que.	CA	88,95
57	Northwestern University	Evanston, IL	US	87,91
58	Institute for Genomic Research	Rockville, MD	US	85,63
59	University of Notre Dame	Notre Dame, IN	US	85,38
60	Dan T Gillespie Consulting	Castaic, CA	US	85,00
61	Case Western Reserve University	Cleveland, OH	US	83,14
62	University of Alberta	Edmonton, Alta.	CA	82,43
63	Purdue University	West Lafayette, IN	US	81,93
64	National University of Singapore	Singapore	SG	80,27
65	Massachusetts General Hospital	Boston, MA	US	78,33
66	Rutgers University	New Brunswick, NJ	US	77,86
67	University of Washington	Seattle, WA	US	77,56
68	Max-Planck-Inst. fÃ¼r Biochemie	Martinsried	DE	76,63
69	University of Rochester	Rochester, NY	US	76,14
70	**University of Groningen**	**NN Haren**	**NL**	**75,62**
71	Cornell University	Ithaca, NY	US	74,75
72	Scripps Research Institute	San Diego, CA	US	73,78
73	University of Illinois	Urbana-Champaign, IL	US	73,17
74	**German Cancer Research Center**	**Heidelberg**	**DE**	**73,16**
75	Forschungszentrum JÃ¼lich	Jülich	DE	72,58
76	University of Arizona	Tucson, AZ 85721	US	71,59
77	Memorial Sloan-Kettering Cancer Center	New York, NY	US	71,19
78	University of Delaware	Newark, DE	US	71,11
79	Ohio State University	Columbus, OH	US	70,58
80	**University of Tübingen**	**Tübingen**	**DE**	**69,63**

81	Peking University	Beijing	CN	69,06
82	University of Copenhagen	Copenhagen	DK	68,94
83	CNR	Rome	IT	67,89
84	University of British Columbia	Vancouver, BC	CA	66,73
85	Utrecht University	Utrecht	NL	66,65
86	University of Maryland	College Park, MD	US	66,20
87	CNRS	Paris	FR	65,78
88	University of Texas	Austin, TX	US	63,41
89	Max Planck Institute for Dynamics of Complex Technical Systems	Magdeburg	DE	63,25
90	Wellcome Trust Genome Campus	Hinxton, Cambridge CB10 1SA	GB	62,67
91	Medical College of Wisconsin	Milwaukee, WI	US	61,62
92	Delft University of Technology	Delft	NL	60,82
93	Whitehead Institute for Biomedical Research	Cambridge, MA	US	60,80
94	Lab. de Biotech. de l'Environnement	Narbonne	FR	60,33
95	Macquarie University	Sydney	AU	57,50
96	**University of Edinburgh**	**Edinburgh**	**GB**	**57,12**
97	Carnegie Mellon University	Pittsburgh, PA	US	57,03
98	University	Blacksburg	US	56,58
99	Harvard Medical School	Boston, MA	US	55,59
100	U.S. Environmental Protection Agency	Research Triangle Park, NC	US	55,25

Note: ERASysBio beneficiaries are highlighted in red.
Source: SCOPUS, Fraunhofer ISI

Figure 30: Comparison of ERASysBio share of top 100 researchh institutions in 2002 and 2007



Source: SCOPUS, Fraunhofer ISI

2.2 Example 2: Bibliometric statistics for Neuroscience/ Neurodegeneration (ERA-NET NEURON)

We have also explored the excellence of NEURON beneficiaries in worldwide comparison. The overall share of NEURON beneficiaries among the top 100 research institutions worldwide in 2007 was with 3% very low (see Table 12Table 11), and this is even less than 2002 (see Figure 31).

Table 12: Top 100 Research institutions in Neuroscience in 2007

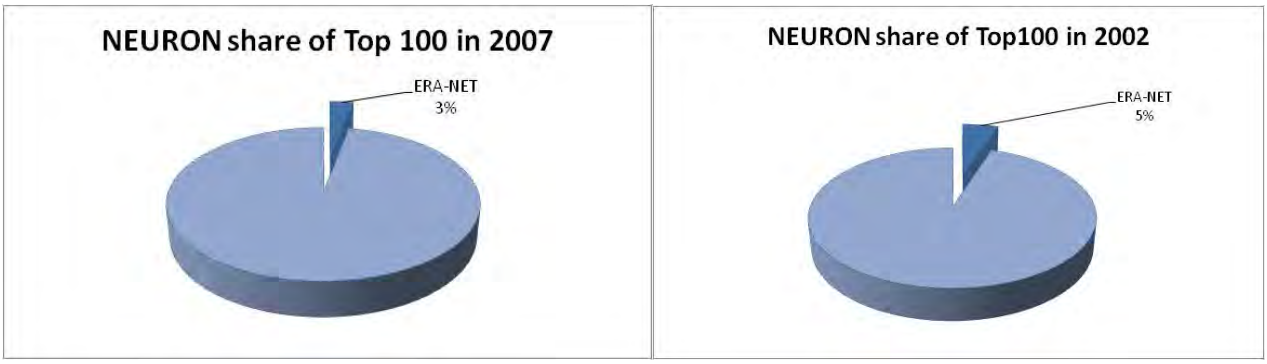
	Organization	City	Country	Citations
1	Baylor College of Medicine	Houston, TX	US	150,09
2	Stanford University School of Medicine	Stanford, CA	US	113,89
3	University of British Columbia	Vancouver, BC	CA	88,00
4	Johns Hopkins University School of Medicine	Baltimore, MD	US	87,74
5	UCLA	Los Angeles, CA	US	77,24
6	Harvard University	Cambridge, MA	US	75,00
7	Harvard Medical School	Boston, MA	US	68,74
8	University of California	San Francisco, CA	US	67,90
9	Nathan Kline Institute	Orangeburg, NY	US	67,81
10	National University of Singapore	Singapore	SG	67,00
11	Cardiff University	Cardiff	GB	65,00
12	Institute of Psychiatry	London	GB	61,32
13	Lilly Corporate Center	Indianapolis, IN	US	61,00
14	University Laval	Sainte-Foy, Que.	CA	59,67
15	National Institute on Aging	Bethesda, MD	US	58,63
16	Fetal and Neonatal Experience on Child and Adolescent Mental Health		US	58,00
17	University of Montreal	Montreal, Que.	CA	56,30
18	Hospital de Bellvitge	Barcelona	ES	56,00
19	**University of Göttingen**	**Göttingen**	**DE**	**54,90**
20	Trinity College	Dublin	IE	54,83
21	University of California	San Diego, CA	US	54,59
22	Harvard Medical School	Boston, MA	US	53,57
23	University of California	Davis, CA	US	50,00
24	Cornell University	New York, NY	US	47,45
25	University of Siena	Siena	IT	47,25
26	Kennedy Krieger Institute	Baltimore, MD	US	46,83
27	Johns Hopkins University	Baltimore, MD	US	46,76
28	Stockholm Gerontology Research Center	Stockholm	SE	45,00
29	University of Toronto	Toronto, Ont.	CA	44,00
30	School of Medicine and Dentistry	Rochester, NY	US	43,79
31	Duke University Medical Center	Durham, NC	US	43,26
32	Partnership for Policy Implementation			42,22
33	Institute of Epidemiology	Neuherberg	DE	41,48
34	VIB	Ghent	BE	41,00
35	Medical University of Vienna	Vienna	AT	40,46
36	University of Kentucky	Lexington, KY	US	40,00
37	Russian Academy of Medical Sciences	Moscow	RU	39,00
38	London School of Hygiene and Tropical Medicine	London	GB	38,11

39	Massachusetts General Hospital	Boston, MA	US	38,03
40	University Hospital	Basel	CH	36,00
41	Columbia University	New York, NY	US	34,06
42	Utrecht University	Utrecht	NL	34,00
43	University of California	Berkeley, CA	US	33,00
44	HagaHospital Leyenburg	The Hague	NL	33,00
45	HagaHospital Leyenburg	The Hague	NL	33,00
46	University of California	Los Angeles, CA	US	32,15
47	University Laval	Quebec, QC	CA	32,00
48	University of Manchester	Manchester	GB	31,86
49	Kanazawa University	Kanazawa	JP	31,23
50	Semel Institute	Los Angeles, CA 90024	US	30,50
51	Vanderbilt University	Nashville, TN	US	30,50
52	Aristotle University of Thessaloniki	Thessaloniki	GR	30,50
53	Federico II University	Naples	IT	30,44
54	Massachusetts Inst of Technology	Cambridge	US	30,42
55	National Institute of Mental Health	Bethesda, MD	US	29,67
56	**Technische Universitaet Muenchen**	**Muenchen**	**DE**	**29,04**
57	University of California	Davis, CA	US	28,97
58	VU University Medical Center	Amsterdam	NL	28,27
59	University of California	Davis, CA	US	28,20
60	Kanazawa University	Kanazawa	JP	28,11
61	Whitehead Institute for Biomedical Research	Cambridge, MA	US	27,75
62	Washington University School of Medicine	St. Louis, MO	US	27,00
63	University of Massachusetts	Amherst, MA	US	26,96
64	World Health Organization	Geneva	CH	26,91
65	Prince of Wales Hospital	Sydney, NSW	AU	26,00
66	University of New South Wales	Sydney, NSW	AU	26,00
67	Emory University	Atlanta, GA	US	25,71
68	University of Wisconsin	Madison, WI	US	25,64
69	University of Oxford	Oxford	GB	25,37
70	Vanderbilt University Medical Center	Nashville, TN	US	25,22
71	University of Cambridge	Cambridge	GB	25,22
72	Universidad Complutense de Madrid	Madrid	ES	25,00
73	Max Planck Institute of Psychiatry	Munich	DE	24,89
74	University of Western Australia	Nedlands, WA	AU	24,67
75	Osaka Univ	Osaka	JP	24,29
76	University of London	London	GB	24,00
77	Louisiana State University Health Sciences Center	New Orleans, LA	US	24,00
78	Baker Heart Research Institute	Melbourne, Vic.	AU	23,64
79	University of Sydney	Sydney, NSW	AU	23,03
80	Imperial Cancer Research Fund	London	GB	23,00
81	Mental Health Research Center	Moscow	RU	23,00
82	Wellcome Trust Genome Campus	Hinxton, Cambridge	GB	23,00
83	University of Washington	Seattle, WA	US	22,62
84	Universität Bonn	Bonn	DE	22,46
85	Columbia University	New York, NY	US	21,96
86	National Institute on Drug Abuse	Bethesda, MD	US	21,86
87	London School of Hygiene and Tropical Medicine	Sangath	IN	21,71

88	Institute of Psychiatry	Rawalpindi	PK	21,71
89	Temple University	Philadelphia, PA	US	21,71
90	Beijing Huilongguan Hospital	Beijing	CN	21,71
91	University of Minnesota	Austin, MN	US	21,67
92	Indiana University School of Medicine	Indianapolis, IN	US	21,60
93	University of Texas Health Science Center	San Antonio, TX	US	21,23
94	Maternal and Child Health Bureau			21,11
95	Macquarie University	Sydney, NSW	AU	21,00
96	Boston University	Boston, MA	US	21,00
97	University of Minnesota	Minneapolis, MN	US	20,86
98	Stavanger University Hospital	Stavanger	NO	20,72
99	DFG Research Center for Molecular Physiology of the Brain (CMPB)	Göttingen	DE	20,67
100	**Karolinska Institute**	**Stockholm**	**SE**	**20,41**

Note: ERASysBio beneficiaries are highlighted in red.
Source: SCOPUS, Fraunhofer ISI

Figure 31: Comparison of ERASysBio share of top 100 researchh institutions in 2002 and 2007



Source: SCOPUS, Fraunhofer ISI

3 Descriptive Statistics

Here, we present descriptive statistics for the variables used in the analyses for explaining Critical Mass achievement in section 6.5 of the Final Report.

Table 13: Descriptive Statistics for the dependent variables

Variable name	N	Minimum	Maximum	Mean	Standard Deviation
A1_SOCIO	48	0	1	0,34	0,32
A1_SCIEN	48	0	1	0,53	0,30
A1_DEFEN	48	0	1	0,49	0,28
A1_PROSP	48	0	1	0,47	0,28
A1_EXCEL	48	0	1	0,38	0,27
A1_SELFS	48	0	1	0,46	0,29

Note: The "A1_..." variables are ratio variables for the achievement of the six types of CM (related to the policy objectives).

Table 14: Descriptive statistics for the independent variables

	N	Minimum	Maximum	Mean	Standard Deviation
NUMPART	48	7	31	17,58	5,20
DIVERS1	48	5	19	12,33	3,38
DIVERS2	48	2	4	3,52	0,65
DIVERS3	39	0	1	0,79	0,41
DIVERS4	39	0	1	0,59	0,50
DIVERS5	47	0	1	0,46	0,20
NUMCALL	48	0	6	1,83	1,46
CALLBUDG	48	0	171.000.000	16.344.965,33	31.773.506,71
AVBUDGET	48	0	7.434.783	817.788,27	1.330.385,12
PARTALLC	48	0	71	15,92	16,27
PARTNERP	48	0	20	7,08	5,29
PARTINVO	48	0	1	0,42	0,30
RDCOMPL	23	0	1	0,26	0,45
COORDFUN	41	88.000	249.433	162.067,86	42.568,74
ACTIVDIV	23	1	6	3,30	1,36
COORDMAN	46	1	4	2,86	0,55
COORDMA0	43	2	4	3,28	0,47
COORDMA1	42	2	4	3,09	0,52
MOTIV_C	23	0	3	1,52	0,85
NUMPROJE	30	0	98	13,63	19,80
PROJECTB	38	66.667	18.000.000	1.131.839,21	2.842.372,82
PROJECTD	40	8	42	29,72	7,22
NOVELRES	44	0	1	0,56	0,37
ORIENTAT	45	0	1	0,72	0,41
BENEFICI	40	2	20	5,12	3,25

4 Correlation Tables

Here, we present the correlation tables for the variables used in section 6.5 of the Final Report.

Table 15: Correlation of variables

		A1_SOCIO	A1_SCIEN	A1_DEFEN	A1_PROSP	A1_EXCEL	A1_SELFS
A1_SOCIO	Correlation (Pearson)	1	**0,6810057**	**0,847042**	**0,8855303**	**0,7852067**	**0,9088322**
	bidirectional Significance	,	1,001E-07	3,243E-14	6,359E-17	3,918E-11	4,384E-19
	N	48	48	48	48	48	48
A1_SCIEN	Correlation (Pearson)	**0,6810057**	1	**0,8680354**	**0,8803395**	**0,9176497**	**0,8511673**
	bidirectional Significance	1,001E-07	,	1,378E-15	1,664E-16	4,654E-20	1,812E-14
	N	48	48	48	48	48	48
A1_DEFEN	Correlation (Pearson)	**0,847042**	**0,8680354**	1	**0,9409866**	**0,8840221**	**0,8967284**
	bidirectional Significance	3,243E-14	1,378E-15	,	2,817E-23	8,45E-17	6,746E-18
	N	48	48	48	48	48	48
A1_PROSP	Correlation (Pearson)	**0,8855303**	**0,8803395**	**0,9409866**	1	**0,9151958**	**0,9784177**
	bidirectional Significance	6,359E-17	1,664E-16	2,817E-23	,	8,901E-20	3,774E-33
	N	48	48	48	48	48	48
A1_EXCEL	Correlation (Pearson)	**0,7852067**	**0,9176497**	**0,8840221**	**0,9151958**	1	**0,9075344**
	bidirectional Significance	3,918E-11	4,654E-20	8,45E-17	8,901E-20	,	5,982E-19
	N	48	48	48	48	48	48
A1_SELFS	Correlation (Pearson)	**0,9088322**	**0,8511673**	**0,8967284**	**0,9784177**	**0,9075344**	1
	bidirectional Significance	4,384E-19	1,812E-14	6,746E-18	3,774E-33	5,982E-19	,
	N	48	48	48	48	48	48
NUMPART	Correlation (Pearson)	0,0850997	0,0433485	-0,0421472	0,0235954	0,0828767	0,0456772
	bidirectional Significance	0,5652294	0,7698678	0,7760783	0,8735218	0,5754684	0,7578694
	N	48	48	48	48	48	48
DIVERS1	Correlation (Pearson)	-0,0115548	-0,0160941	-0,1120479	-0,0563605	0,0025623	-0,0478156
	bidirectional Significance	0,9378707	0,9135429	0,448319	0,703584	0,9862098	0,7469009
	N	48	48	48	48	48	48
DIVERS2	Correlation (Pearson)	0,0390663	0,2115096	0,1171812	0,1100925	0,1867489	0,0989227
	bidirectional Significance	0,7920684	0,1489812	0,4276653	0,4563284	0,2037483	0,5035373
	N	48	48	48	48	48	48
DIVERS3	Correlation (Pearson)	0,0477052	-0,2078599	-0,0288061	-0,0728287	-0,1231814	-0,124542
	bidirectional Significance	0,7730482	0,2041655	0,861805	0,6595001	0,4550085	0,4500043
	N	39	39	39	39	39	39
DIVERS4	Correlation (Pearson)	0,2623398	-0,0613973	0,1256275	0,1009911	0,1044931	0,1041385
	bidirectional Significance	0,1066557	0,7104127	0,4460333	0,5407122	0,5266916	0,5281031
	N	39	39	39	39	39	39
DIVERS5	Correlation (Pearson)	0,2635023	0,2717201	0,2782776	**0,3240074**	**0,2906277**	**0,3515495**
	bidirectional Significance	0,0735162	0,0646618	0,0582246	0,0262979	0,0475019	0,0153884
	N	47	47	47	47	47	47
NUMCALL	Correlation (Pearson)	**0,4110257**	0,2176514	0,2771894	**0,3253302**	0,2396053	**0,3754727**
	bidirectional Significance	0,0037071	0,137262	0,0564735	0,0240514	0,1009495	0,0085443
	N	48	48	48	48	48	48
CALLBUDG	Correlation (Pearson)	**0,3968499**	0,2754226	**0,3768003**	**0,3136497**	0,2795348	**0,3018028**
	bidirectional Significance	0,0052275	0,0581307	0,0082951	0,0299421	0,0543326	0,0370947
	N	48	48	48	48	48	48
AVBUDGET	Correlation (Pearson)	0,2801164	0,2198614	**0,2849114**	0,2201721	0,1649927	0,2109965
	bidirectional Significance	0,053812	0,1332178	0,0496714	0,1326564	0,2624272	0,1499927
	N	48	48	48	48	48	48

(Table 15 continued)

		NUMPART	DIVERS1	DIVERS2	DIVERS3	DIVERS4	DIVERS5
A1_SOCIO	Correlation (Pearson)	0,0850997	-0,011555	0,0390663	0,0477052	0,2623398	0,2635023
	bidirectional Significance	0,5652294	0,9378707	0,7920684	0,7730482	0,1066557	0,0735162
	N	48	48	48	39	39	47
A1_SCIEN	Correlation (Pearson)	0,0433485	-0,016094	0,2115096	-0,20786	-0,061397	0,2717201
	bidirectional Significance	0,7698678	0,9135429	0,1489812	0,2041655	0,7104127	0,0646618
	N	48	48	48	39	39	47
A1_DEFEN	Correlation (Pearson)	-0,042147	-0,112048	0,1171812	-0,028806	0,1256275	0,2782776
	bidirectional Significance	0,7760783	0,448319	0,4276653	0,861805	0,4460333	0,0582246
	N	48	48	48	39	39	47
A1_PROSP	Correlation (Pearson)	0,0235954	-0,056361	0,1100925	-0,072829	0,1009911	**0,3240074**
	bidirectional Significance	0,8735218	0,703584	0,4563284	0,6595001	0,5407122	0,0262979
	N	48	48	48	39	39	47
A1_EXCEL	Correlation (Pearson)	0,0828767	0,0025623	0,1867489	-0,123181	0,1044931	**0,2906277**
	bidirectional Significance	0,5754684	0,9862098	0,2037483	0,4550085	0,5266916	0,0475019
	N	48	48	48	39	39	47
A1_SELFS	Correlation (Pearson)	0,0456772	-0,047816	0,0989227	-0,124542	0,1041385	**0,3515495**
	bidirectional Significance	0,7578694	0,7469009	0,5035373	0,4500043	0,5281031	0,0153884
	N	48	48	48	39	39	47
NUMPART	Correlation (Pearson)	1	**0,7918796**	**0,3918926**	-0,025095	-0,012162	-0,178532
	bidirectional Significance	,	2,05E-11	0,005875	0,8794667	0,9414205	0,2298802
	N	48	48	48	39	39	47
DIVERS1	Correlation (Pearson)	**0,7918796**	1	**0,5569085**	0,1295695	0,0764752	-0,155437
	bidirectional Significance	2,05E-11	,	3,94E-05	0,4317754	0,6435598	0,2968159
	N	48	48	48	39	39	47
DIVERS2	Correlation (Pearson)	**0,3918926**	**0,5569085**	1	0,1309087	0,2149317	-0,001453
	bidirectional Significance	0,005875	3,94E-05	,	0,4269897	0,1888476	0,9922684
	N	48	48	48	39	39	47
DIVERS3	Correlation (Pearson)	-0,025095	0,1295695	0,1309087	1	**0,6090712**	**-0,329392**
	bidirectional Significance	0,8794667	0,4317754	0,4269897	,	3,876E-05	0,0405927
	N	39	39	39	39	39	39
DIVERS4	Correlation (Pearson)	-0,012162	0,0764752	0,2149317	**0,6090712**	1	0,1027849
	bidirectional Significance	0,9414205	0,6435598	0,1888476	3,876E-05	,	0,533508
	N	39	39	39	39	39	39
DIVERS5	Correlation (Pearson)	-0,178532	-0,155437	-0,001453	**-0,329392**	0,1027849	1
	bidirectional Significance	0,2298802	0,2968159	0,9922684	0,0405927	0,533508	,
	N	47	47	47	39	39	47
NUMCALL	Correlation (Pearson)	0,0494159	0,0587987	0,0483126	0,1140007	0,1871714	0,1376575
	bidirectional Significance	0,7387246	0,6913861	0,7443585	0,4895472	0,253881	0,3561515
	N	48	48	48	39	39	47
CALLBUDG	Correlation (Pearson)	-0,052728	-0,122717	-0,164027	0,1019502	0,0802744	0,1486516
	bidirectional Significance	0,7218925	0,4060061	0,2652691	0,5368546	0,6271173	0,3186595
	N	48	48	48	39	39	47
AVBUDGET	Correlation (Pearson)	-0,189937	-0,229363	-0,209977	-0,100767	-0,030699	0,1121248
	bidirectional Significance	0,1959964	0,1168411	0,1520172	0,5416169	0,8528197	0,4530375
	N	48	48	48	39	39	47

(Table 15 continued)

		NUMCALL	CALLBUDG	AVBUDGET	PARTALLC	PARTNERP	PARTINVO
A1_SOCIO	Correlation (Pearson)	**0,4110257**	**0,3968499**	0,2801164	**0,6148353**	**0,5019364**	**0,4435525**
	bidirectional Significance	0,0037071	0,0052275	0,053812	3,33E-06	0,0002782	0,0015907
	N	48	48	48	48	48	48
A1_SCIEN	Correlation (Pearson)	0,2176514	0,2754226	0,2198614	**0,4260404**	**0,5127517**	**0,4595477**
	bidirectional Significance	0,137262	0,0581307	0,1332178	0,0025344	0,0001944	0,0010169
	N	48	48	48	48	48	48
A1_DEFEN	Correlation (Pearson)	0,2771894	**0,3768003**	**0,2849114**	**0,5238923**	**0,5332042**	**0,5163537**
	bidirectional Significance	0,0564735	0,0082951	0,0496714	0,0001327	9,541E-05	0,0001721
	N	48	48	48	48	48	48
A1_PROSP	Correlation (Pearson)	**0,3253302**	**0,3136497**	0,2201721	**0,5429266**	**0,5814938**	**0,5487621**
	bidirectional Significance	0,0240514	0,0299421	0,1326564	6,692E-05	1,463E-05	5,38E-05
	N	48	48	48	48	48	48
A1_EXCEL	Correlation (Pearson)	0,2396053	0,2795348	0,1649927	**0,5316263**	**0,5935289**	**0,5236217**
	bidirectional Significance	0,1009495	0,0543326	0,2624272	0,000101	8,737E-06	0,0001339
	N	48	48	48	48	48	48
A1_SELFS	Correlation (Pearson)	**0,3754727**	**0,3018028**	0,2109965	**0,5511731**	**0,5462783**	**0,5105044**
	bidirectional Significance	0,0085443	0,0370947	0,1499927	4,911E-05	5,907E-05	0,0002096
	N	48	48	48	48	48	48
NUMPART	Correlation (Pearson)	0,0494159	-0,052728	-0,189937	0,2205413	0,0975203	-0,255255
	bidirectional Significance	0,7387246	0,7218925	0,1959964	0,1319917	0,5096358	0,0799493
	N	48	48	48	48	48	48
DIVERS1	Correlation (Pearson)	0,0587987	-0,122717	-0,229363	0,2265773	0,1293285	-0,18482
	bidirectional Significance	0,6913861	0,4060061	0,1168411	0,121475	0,3809849	0,2085411
	N	48	48	48	48	48	48
DIVERS2	Correlation (Pearson)	0,0483126	-0,164027	-0,209977	0,1105088	0,0728655	-0,125517
	bidirectional Significance	0,7443585	0,2652691	0,1520172	0,4546166	0,6225958	0,3952938
	N	48	48	48	48	48	48
DIVERS3	Correlation (Pearson)	0,1140007	0,1019502	-0,100767	0,2497974	0,2936621	0,2974189
	bidirectional Significance	0,4895472	0,5368546	0,5416169	0,1251138	0,069602	0,0659434
	N	39	39	39	39	39	39
DIVERS4	Correlation (Pearson)	0,1871714	0,0802744	-0,030699	0,2481852	0,124208	0,0691676
	bidirectional Significance	0,253881	0,6271173	0,8528197	0,1276495	0,4512298	0,6756552
	N	39	39	39	39	39	39
DIVERS5	Correlation (Pearson)	0,1376575	0,1486516	0,1121248	0,1225479	0,038572	0,0569296
	bidirectional Significance	0,3561515	0,3186595	0,4530375	0,4118611	0,7968611	0,7038798
	N	47	47	47	47	47	47
NUMCALL	Correlation (Pearson)	1	**0,353579**	0,198247	**0,7456967**	**0,3869143**	**0,3270877**
	bidirectional Significance	,	0,0136896	0,1767783	1,194E-09	0,0065944	0,0232554
	N	48	48	48	48	48	48
CALLBUDG	Correlation (Pearson)	**0,353579**	1	**0,8739064**	**0,4675658**	**0,3154238**	**0,3103725**
	bidirectional Significance	0,0136896	,	5,166E-16	0,0008059	0,028977	0,0317952
	N	48	48	48	48	48	48
AVBUDGET	Correlation (Pearson)	0,198247	**0,8739064**	1	0,157083	0,1449451	0,2137752
	bidirectional Significance	0,1767783	5,166E-16	,	0,2863096	0,325636	0,1445753
	N	48	48	48	48	48	48

(Table 15 continued)

		RDCOMPL	COORDFUN	ACTIVDIV	COORDMAN	COORDMA0	COORDMA1
A1_SOCIO	Correlation (Pearson)	-0,2569508	**0,1428751**	-0,0436519	0,2749893	0,0572653	**-0,0480183**
	bidirectional Significance	0,2365819	0,3728545	0,843228	0,0643746	0,7152994	0,7626697
	N	23	41	23	46	43	42
A1_SCIEN	Correlation (Pearson)	0,0501626	**0,1356634**	0,3956046	**0,3393111**	0,235745	0,006882
	bidirectional Significance	0,820192	0,3977058	0,0616914	0,0210608	0,1280413	0,9654983
	N	23	41	23	46	43	42
A1_DEFEN	Correlation (Pearson)	0,0706438	**0,1883537**	0,0545968	**0,3882721**	0,2156492	0,1091624
	bidirectional Significance	0,7487388	0,2382602	0,8045837	0,0076663	0,1648812	0,4913494
	N	23	41	23	46	43	42
A1_PROSP	Correlation (Pearson)	0,069383	**0,1936784**	0,0208238	**0,3474717**	0,18737	0,0125418
	bidirectional Significance	0,7530865	0,225006	0,9248644	0,0179786	0,2289172	0,9371674
	N	23	41	23	46	43	42
A1_EXCEL	Correlation (Pearson)	-0,0084788	**0,0294154**	0,1948107	0,278689	0,1682769	0,0045885
	bidirectional Significance	0,9693722	0,8551395	0,3730603	0,0607254	0,2807374	0,9769926
	N	23	41	23	46	43	42
A1_SELFS	Correlation (Pearson)	-0,0292332	**0,214493**	0,0349076	**0,3062042**	0,1596556	-0,0406109
	bidirectional Significance	0,8946624	0,1780812	0,87436	0,0384872	0,3064686	0,7984516
	N	23	41	23	46	43	42
NUMPART	Correlation (Pearson)	-0,1894716	**-0,6231365**	0,1808821	-0,021726	-0,0665442	-0,0454858
	bidirectional Significance	0,3865546	1,353E-05	0,4088328	0,886042	0,6715866	0,7748526
	N	23	41	23	46	43	42
DIVERS1	Correlation (Pearson)	-0,0917256	**-0,4288504**	**0,1715796**	0,1013121	0,1275557	0,1964958
	bidirectional Significance	0,6772284	0,0051475	0,4337385	0,5028903	0,4149986	0,2123207
	N	23	41	23	46	43	42
DIVERS2	Correlation (Pearson)	0,2958907	-0,179714	0,2071221	**0,3442068**	**0,464611**	**0,4458109**
	bidirectional Significance	0,1704266	0,260874	0,3429938	0,0191625	0,0016968	0,0030873
	N	23	41	23	46	43	42
DIVERS3	Correlation (Pearson)	-0,1669931	-0,0970028	-0,3541213	-0,0016205	0,1259508	0,2819865
	bidirectional Significance	0,4463101	0,5793428	0,0973534	0,9922958	0,4641946	0,1007629
	N	23	35	23	38	36	35
DIVERS4	Correlation (Pearson)	-0,1898142	-0,1822672	-0,2441514	0,038787	0,1793193	0,2247642
	bidirectional Significance	0,3856806	0,2946588	0,2615617	0,8171604	0,2953502	0,1942479
	N	23	35	23	38	36	35
DIVERS5	Correlation (Pearson)	-0,0015382	0,2652727	0,1871028	0,2857301	0,097603	-0,0884326
	bidirectional Significance	0,9944424	0,0980627	0,3926288	0,0570828	0,5386066	0,5824478
	N	23	40	23	45	42	41
NUMCALL	Correlation (Pearson)	-0,2470107	**-0,0059841**	-0,0114602	0,1710027	-0,1171515	-0,1428183
	bidirectional Significance	0,2558405	0,9703796	0,9586101	0,2558426	0,4543643	0,3669118
	N	23	41	23	46	43	42
CALLBUDG	Correlation (Pearson)	-0,1040025	**0,1711359**	0,184565	**0,2997123**	0,0199047	0,0903313
	bidirectional Significance	0,6367501	0,2846943	0,3991953	0,0430126	0,8991856	0,569416
	N	23	41	23	46	43	42
AVBUDGET	Correlation (Pearson)	0,1210525	**0,346**	0,2659367	0,2431894	0,0287019	0,0894885
	bidirectional Significance	0,5821805	0,0265579	0,2200111	0,1034079	0,8550317	0,5730384
	N	23	41	23	46	43	42

(Table 15 continued)

		MOTIV_C	NUMPROJE	PROJECTB	PROJECTD	NOVELRES	ORIENTAT	BENEFICI
A1_SOCIO	Correlation (Pearson)	-0,17066	**0,534916**	-0,15619	-0,03627	-0,03863	**0,341269**	-0,22248
	bidirectional Significance	0,436245	0,002322	0,349056	0,824161	0,80338	0,021777	0,167629
	N	23	30	38	40	44	45	40
A1_SCIEN	Correlation (Pearson)	0,103518	**0,422396**	-0,14988	0,078021	0,266497	0,00175	-0,19386
	bidirectional Significance	0,638329	0,020057	0,369123	0,632271	0,080356	0,990895	0,230668
	N	23	30	38	40	44	45	40
A1_DEFEN	Correlation (Pearson)	-0,09081	**0,452779**	-0,1451	0,05389	0,209421	0,095619	-0,24972
	bidirectional Significance	0,680273	0,01199	0,384736	0,741201	0,172463	0,532094	0,120177
	N	23	30	38	40	44	45	40
A1_PROSP	Correlation (Pearson)	-0,03046	**0,48728**	-0,22005	0,00088	0,125592	0,21261	-0,273
	bidirectional Significance	0,890251	0,006312	0,184347	0,9957	0,416607	0,16086	0,088301
	N	23	30	38	40	44	45	40
A1_EXCEL	Correlation (Pearson)	-0,00968	**0,49266**	-0,12045	0,011131	0,140763	0,154874	-0,2778
	bidirectional Significance	0,96505	0,005678	0,471319	0,945653	0,362091	0,309707	0,082632
	N	23	30	38	40	44	45	40
A1_SELFS	Correlation (Pearson)	-0,06027	**0,46691**	-0,22502	-0,00338	0,099209	0,292059	-0,26856
	bidirectional Significance	0,784729	0,009291	0,174376	0,983491	0,521709	0,051566	0,093817
	N	23	30	38	40	44	45	40
NUMPART	Correlation (Pearson)	0,073463	0,04793	0,230421	-0,06381	-0,08505	-0,02956	0,233355
	bidirectional Significance	0,739046	0,801418	0,163991	0,695654	0,58305	0,84713	0,147292
	N	23	30	38	40	44	45	40
DIVERS1	Correlation (Pearson)	-0,0362	0,175488	**0,325004**	-0,04917	-0,10881	-0,09448	**0,447123**
	bidirectional Significance	0,869741	0,353629	0,046487	0,763183	0,481989	0,537013	0,003821
	N	23	30	38	40	44	45	40
DIVERS2	Correlation (Pearson)	-0,06217	-0,04035	0,13367	0,115889	-0,00517	-0,09105	0,205081
	bidirectional Significance	0,778091	0,83235	0,423669	0,476398	0,97341	0,551971	0,204278
	N	23	30	38	40	44	45	40
DIVERS3	Correlation (Pearson)	-0,30471	0,224251	0,03933	-0,08634	-0,14778	0,189481	0,036475
	bidirectional Significance	0,157442	0,315723	0,819848	0,611361	0,375924	0,254544	0,830296
	N	23	22	36	37	38	38	37
DIVERS4	Correlation (Pearson)	-0,09116	0,194734	0,190739	-0,05275	-0,17514	0,053818	-0,11739
	bidirectional Significance	0,679112	0,385162	0,265145	0,75649	0,292927	0,748283	0,488972
	N	23	22	36	37	38	38	37
DIVERS5	Correlation (Pearson)	0,343327	-0,03691	0,056681	0,176089	0,152422	-0,04726	0,115791
	bidirectional Significance	0,108735	0,849239	0,735359	0,283584	0,323282	0,760635	0,482707
	N	23	29	38	39	44	44	39
NUMCALL	Correlation (Pearson)	0,120037	**0,395572**	-0,23633	-0,05313	-0,17656	0,234464	-0,10661
	bidirectional Significance	0,585372	0,030487	0,153145	0,744726	0,251592	0,121076	0,51263
	N	23	30	38	40	44	45	40
CALLBUDG	Correlation (Pearson)	-0,15288	**0,590878**	-0,00903	0,205189	0,086695	-0,11952	-0,13075
	bidirectional Significance	0,486177	0,000586	0,957074	0,204033	0,575773	0,434212	0,421313
	N	23	30	38	40	44	45	40
AVBUDGET	Correlation (Pearson)	-0,02504	0,267983	-0,00601	0,292432	0,11266	-0,27343	-0,08171
	bidirectional Significance	0,909695	0,152208	0,971431	0,067084	0,466544	0,069154	0,61621
	N	23	30	38	40	44	45	40

(Table 15 continued)

		A1_SOCIO	A1_SCIEN	A1_DEFEN	A1_PROSP	A1_EXCEL	A1_SELFS
PARTALLC	Correlation (Pearson)	**0,6148353**	**0,4260404**	**0,5238923**	**0,5429266**	**0,5316263**	**0,5511731**
	bidirectional Significance	3,33E-06	0,0025344	0,0001327	6,692E-05	0,000101	4,911E-05
	N	48	48	48	48	48	48
PARTNERP	Correlation (Pearson)	**0,5019364**	**0,5127517**	**0,5332042**	**0,5814938**	**0,5935289**	**0,5462783**
	bidirectional Significance	0,0002782	0,0001944	9,541E-05	1,463E-05	8,737E-06	5,907E-05
	N	48	48	48	48	48	48
PARTINVO	Correlation (Pearson)	**0,4435525**	**0,4595477**	**0,5163537**	**0,5487621**	**0,5236217**	**0,5105044**
	bidirectional Significance	0,0015907	0,0010169	0,0001721	5,38E-05	0,0001339	0,0002096
	N	48	48	48	48	48	48
RDCOMPL	Correlation (Pearson)	-0,256951	0,0501626	0,0706438	0,069383	-0,008479	-0,029233
	bidirectional Significance	0,2365819	0,820192	0,7487388	0,7530865	0,9693722	0,8946624
	N	23	23	23	23	23	23
COORDFUN	Correlation (Pearson)	0,1428751	0,1356634	0,1883537	0,1936784	0,0294154	0,214493
	bidirectional Significance	0,3728545	0,3977058	0,2382602	0,225006	0,8551395	0,1780812
	N	41	41	41	41	41	41
ACTIVDIV	Correlation (Pearson)	-0,043652	0,3956046	0,0545968	0,0208238	0,1948107	0,0349076
	bidirectional Significance	0,843228	0,0616914	0,8045837	0,9248644	0,3730603	0,87436
	N	23	23	23	23	23	23
COORDMAN	Correlation (Pearson)	0,2749893	**0,3393111**	**0,3882721**	**0,3474717**	0,278689	**0,3062042**
	bidirectional Significance	0,0643746	0,0210608	0,0076663	0,0179786	0,0607254	0,0384872
	N	46	46	46	46	46	46
COORDMA0	Correlation (Pearson)	0,0572653	0,235745	0,2156492	0,18737	0,1682769	0,1596556
	bidirectional Significance	0,7152994	0,1280413	0,1648812	0,2289172	0,2807374	0,3064686
	N	43	43	43	43	43	43
COORDMA1	Correlation (Pearson)	-0,048018	0,006882	0,1091624	0,0125418	0,0045885	-0,040611
	bidirectional Significance	0,7626697	0,9654983	0,4913494	0,9371674	0,9769926	0,7984516
	N	42	42	42	42	42	42
MOTIV_C	Correlation (Pearson)	-0,17066	0,1035181	-0,090813	-0,030465	-0,009676	-0,060267
	bidirectional Significance	0,4362447	0,6383291	0,6802734	0,8902505	0,9650504	0,7847295
	N	23	23	23	23	23	23
NUMPROJE	Correlation (Pearson)	**0,5349158**	**0,4223961**	**0,4527793**	**0,48728**	**0,49266**	**0,4669103**
	bidirectional Significance	0,0023225	0,0200571	0,0119896	0,0063124	0,0056777	0,0092907
	N	30	30	30	30	30	30
PROJECTB	Correlation (Pearson)	-0,15619	-0,149875	-0,145102	-0,220047	-0,120451	-0,22502
	bidirectional Significance	0,3490563	0,3691231	0,3847357	0,1843471	0,4713191	0,174376
	N	38	38	38	38	38	38
PROJECTD	Correlation (Pearson)	-0,036271	0,0780213	0,0538901	0,0008801	0,0111307	-0,003379
	bidirectional Significance	0,8241613	0,6322708	0,7412012	0,9956997	0,9456531	0,9834909
	N	40	40	40	40	40	40
NOVELRES	Correlation (Pearson)	-0,038633	0,2664965	0,2094205	0,1255916	0,1407634	0,0992086
	bidirectional Significance	0,8033801	0,0803558	0,1724632	0,4166073	0,3620911	0,5217085
	N	44	44	44	44	44	44
ORIENTAT	Correlation (Pearson)	**0,3412691**	0,0017504	0,0956186	0,2126096	0,1548739	0,2920588
	bidirectional Significance	0,0217769	0,9908952	0,5320936	0,1608602	0,3097075	0,0515664
	N	45	45	45	45	45	45
BENEFICI	Correlation (Pearson)	-0,222485	-0,193865	-0,249721	-0,273005	-0,277803	-0,268559
	bidirectional Significance	0,167629	0,2306683	0,1201769	0,0883005	0,0826322	0,0938171
	N	40	40	40	40	40	40

(Table 15 continued)

		NUMPART	DIVERS1	DIVERS2	DIVERS3	DIVERS4	DIVERS5
PARTALLC	Correlation (Pearson)	0,2205413	0,2265773	0,1105088	0,2497974	0,2481852	0,1225479
	bidirectional Significance	0,1319917	0,121475	0,4546166	0,1251138	0,1276495	0,4118611
	N	48	48	48	39	39	47
PARTNERP	Correlation (Pearson)	0,0975203	0,1293285	0,0728655	0,2936621	0,124208	0,038572
	bidirectional Significance	0,5096358	0,3809849	0,6225958	0,069602	0,4512298	0,7968611
	N	48	48	48	39	39	47
PARTINVO	Correlation (Pearson)	-0,2552555	-0,1848204	-0,1255174	0,2974189	0,0691676	0,0569296
	bidirectional Significance	0,0799493	0,2085411	0,3952938	0,0659434	0,6756552	0,7038798
	N	48	48	48	39	39	47
RDCOMPL	Correlation (Pearson)	-0,1894716	-0,0917256	0,2958907	-0,1669931	-0,1898142	-0,0015382
	bidirectional Significance	0,3865546	0,6772284	0,1704266	0,4463101	0,3856806	0,9944424
	N	23	23	23	23	23	23
COORDFUN	Correlation (Pearson)	**-0,6231365**	**-0,4288504**	-0,179714	-0,0970028	-0,1822672	0,2652727
	bidirectional Significance	1,353E-05	0,0051475	0,260874	0,5793428	0,2946588	0,0980627
	N	41	41	41	35	35	40
ACTIVDIV	Correlation (Pearson)	0,1808821	0,1715796	0,2071221	-0,3541213	-0,2441514	0,1871028
	bidirectional Significance	0,4088328	0,4337385	0,3429938	0,0973534	0,2615617	0,3926288
	N	23	23	23	23	23	23
COORDMAN	Correlation (Pearson)	-0,021726	0,1013121	**0,3442068**	-0,0016205	0,038787	0,2857301
	bidirectional Significance	0,886042	0,5028903	0,0191625	0,9922958	0,8171604	0,0570828
	N	46	46	46	38	38	45
COORDMA0	Correlation (Pearson)	-0,0665442	0,1275557	**0,464611**	0,1259508	0,1793193	0,097603
	bidirectional Significance	0,6715866	0,4149986	0,0016968	0,4641946	0,2953502	0,5386066
	N	43	43	43	36	36	42
COORDMA1	Correlation (Pearson)	-0,0454858	0,1964958	**0,4458109**	0,2819865	0,2247642	-0,0884326
	bidirectional Significance	0,7748526	0,2123207	0,0030873	0,1007629	0,1942479	0,5824478
	N	42	42	42	35	35	41
MOTIV_C	Correlation (Pearson)	0,0734625	-0,0362016	-0,0621712	-0,3047103	-0,0911609	0,3433266
	bidirectional Significance	0,7390459	0,8697407	0,7780909	0,157442	0,6791122	0,1087347
	N	23	23	23	23	23	23
NUMPROJE	Correlation (Pearson)	0,0479299	0,1754884	-0,0403475	0,2242508	0,194734	-0,0369104
	bidirectional Significance	0,8014183	0,3536289	0,8323505	0,3157233	0,3851619	0,8492388
	N	30	30	30	22	22	29
PROJECTB	Correlation (Pearson)	0,2304212	**0,3250036**	0,13367	0,0393301	0,190739	0,0566811
	bidirectional Significance	0,1639911	0,0464866	0,4236694	0,8198482	0,2651448	0,7353588
	N	38	38	38	36	36	38
PROJECTD	Correlation (Pearson)	-0,0638135	-0,0491706	0,1158886	-0,0863435	-0,0527541	0,176089
	bidirectional Significance	0,6956542	0,7631834	0,4763984	0,6113614	0,7564903	0,2835836
	N	40	40	40	37	37	39
NOVELRES	Correlation (Pearson)	-0,0850534	-0,1088145	-0,0051738	-0,1477817	-0,1751392	0,1524225
	bidirectional Significance	0,5830503	0,4819893	0,9734102	0,375924	0,2929273	0,3232817
	N	44	44	44	38	38	44
ORIENTAT	Correlation (Pearson)	-0,0295639	-0,0944794	-0,0910465	0,1894812	0,0538176	-0,0472622
	bidirectional Significance	0,8471298	0,5370132	0,5519712	0,2545443	0,748283	0,7606348
	N	45	45	45	38	38	44
BENEFICI	Correlation (Pearson)	0,2333554	**0,4471226**	0,2050806	0,0364745	-0,1173899	0,1157911
	bidirectional Significance	0,147292	0,0038212	0,2042777	0,830296	0,4889719	0,4827074
	N	40	40	40	37	37	39

(Table 15 continued)

		NUMCALL	CALLBUDG	AVBUDGET	PARTALLC	PARTNERP	PARTINVO
PARTALLC	Correlation (Pearson)	**0,7456967**	**0,4675658**	0,157083	1	**0,7343777**	**0,5682317**
	bidirectional Significance	1,194E-09	0,0008059	0,2863096	,	2,84E-09	2,521E-05
	N	48	48	48	48	48	48
PARTNERP	Correlation (Pearson)	**0,3869143**	**0,3154238**	0,1449451	**0,7343777**	1	**0,8940082**
	bidirectional Significance	0,0065944	0,028977	0,325636	2,84E-09	,	1,19E-17
	N	48	48	48	48	48	48
PARTINVO	Correlation (Pearson)	**0,3270877**	**0,3103725**	0,2137752	**0,5682317**	**0,8940082**	1
	bidirectional Significance	0,0232554	0,0317952	0,1445753	2,521E-05	1,19E-17	,
	N	48	48	48	48	48	48
RDCOMPL	Correlation (Pearson)	-0,247010	-0,104002	0,1210525	-0,252595	0,1388758	0,1813507
	bidirectional Significance	0,2558405	0,6367501	0,5821805	0,2449004	0,527415	0,4075994
	N	23	23	23	23	23	23
COORDFUN	Correlation (Pearson)	-0,005984	0,1711359	**0,3462995**	-0,210318	-0,081486	0,2215754
	bidirectional Significance	0,9703796	0,2846943	0,0265579	0,1868797	0,6125215	0,1638393
	N	41	41	41	41	41	41
ACTIVDIV	Correlation (Pearson)	-0,011460	0,184565	0,2659367	-0,036746	-0,059192	-0,114622
	bidirectional Significance	0,9586101	0,3991953	0,2200111	0,8677957	0,7884813	0,6025214
	N	23	23	23	23	23	23
COORDMAN	Correlation (Pearson)	0,1710027	**0,2997123**	0,2431894	0,2134423	0,1196532	0,0692073
	bidirectional Significance	0,2558426	0,0430126	0,1034079	0,1543686	0,4283342	0,6476584
	N	46	46	46	46	46	46
COORDMA0	Correlation (Pearson)	-0,117151	0,0199047	0,0287019	-0,057725	0,0497362	0,0078679
	bidirectional Significance	0,4543643	0,8991856	0,8550317	0,7131099	0,7514503	0,9600635
	N	43	43	43	43	43	43
COORDMA1	Correlation (Pearson)	-0,142818	0,0903313	0,0894885	0,0429087	0,0840175	0,0282654
	bidirectional Significance	0,3669118	0,569416	0,5730384	0,7873047	0,5968053	0,858968
	N	42	42	42	42	42	42
MOTIV_C	Correlation (Pearson)	0,1200374	-0,152878	-0,0250435	-0,072415	-0,160225	-0,325694
	bidirectional Significance	0,5853721	0,486177	0,9096945	0,7426428	0,4652074	0,129375
	N	23	23	23	23	23	23
NUMPROJE	Correlation (Pearson)	**0,3955718**	**0,5908776**	0,2679831	**0,645863**	**0,702971**	**0,6186301**
	bidirectional Significance	0,0304873	0,0005861	0,1522078	0,0001158	1,479E-05	0,0002685
	N	30	30	30	30	30	30
PROJECTB	Correlation (Pearson)	-0,236332	-0,009033	-0,0060105	-0,173137	-0,253240	-0,287152
	bidirectional Significance	0,1531449	0,9570736	0,971431	0,2985646	0,1250153	0,0804608
	N	38	38	38	38	38	38
PROJECTD	Correlation (Pearson)	-0,053130	0,205189	0,292432	-0,053632	-0,093049	-0,097394
	bidirectional Significance	0,7447264	0,2040335	0,0670837	0,7423948	0,5679491	0,5499275
	N	40	40	40	40	40	40
NOVELRES	Correlation (Pearson)	-0,176561	0,0866949	0,1126604	-0,128843	-0,059631	-0,089971
	bidirectional Significance	0,2515919	0,5757734	0,4665439	0,4045446	0,7006035	0,5613721
	N	44	44	44	44	44	44
ORIENTAT	Correlation (Pearson)	0,2344641	-0,119518	-0,2734296	0,2149943	0,1491935	0,1374783
	bidirectional Significance	0,1210762	0,4342123	0,0691538	0,1561067	0,3280024	0,3678185
	N	45	45	45	45	45	45
BENEFICI	Correlation (Pearson)	-0,106609	-0,130745	-0,0817096	-0,162126	-0,184561	-0,245425
	bidirectional Significance	0,5126295	0,4213127	0,6162096	0,3175544	0,2542511	0,1268998
	N	40	40	40	40	40	40

(Table 15 continued)

		RDCOMPL	COORDFUN	ACTIVDIV	COORDMAN	COORDMA0	COORDMA1
PARTALLC	Correlation (Pearson)	-0,2525951	-0,2103183	-0,0367467	0,21344232	-0,0577253	0,04290869
	bidirectional Significance	0,24490044	0,1868797	0,86779572	0,15436855	0,71310989	0,7873047
	N	23	41	23	46	43	42
PARTNERP	Correlation (Pearson)	0,13887577	-0,0814867	-0,0591929	0,1196532	0,04973617	0,08401748
	bidirectional Significance	0,527415	0,61252154	0,78848126	0,42833421	0,75145035	0,59680526
	N	23	41	23	46	43	42
PARTINVO	Correlation (Pearson)	0,18135072	0,22157538	-0,1146228	0,06920731	0,00786793	0,02826541
	bidirectional Significance	0,40759943	0,1638393	0,60252143	0,64765836	0,9600635	0,85896796
	N	23	41	23	46	43	42
RDCOMPL	Correlation (Pearson)	1	0,16389309	-0,0613606	0,20050221	**0,42907211**	0,4064765
	bidirectional Significance	,	0,48991174	0,78091538	0,35897772	0,04630044	0,06048509
	N	23	20	23	23	22	22
COORDFUN	Correlation (Pearson)	0,16389309	1	0,09705431	0,00731602	-0,109468	-0,2375985
	bidirectional Significance	0,48991174	,	0,683967	0,96426365	0,50708522	0,15089107
	N	20	41	20	40	39	38
ACTIVDIV	Correlation (Pearson)	-0,0613606	0,09705431	1	0,11151364	-0,1496026	-0,2671013
	bidirectional Significance	0,78091538	0,683967	,	0,61246257	0,50637402	0,22949116
	N	23	20	23	23	22	22
COORDMAN	Correlation (Pearson)	0,20050221	0,00731602	0,11151364	1	**0,55419741**	**0,53841105**
	bidirectional Significance	0,35897772	0,96426365	0,61246257	,	0,00011536	0,00023503
	N	23	40	23	46	43	42
COORDMA0	Correlation (Pearson)	**0,42907211**	-0,109468	-0,1496026	**0,55419741**	1	**0,83563301**
	bidirectional Significance	0,04630044	0,50708522	0,50637402	0,00011536	,	5,8053E-12
	N	22	39	22	43	43	42
COORDMA1	Correlation (Pearson)	0,4064765	-0,2375985	-0,2671013	**0,53841105**	**0,83563301**	1
	bidirectional Significance	0,06048509	0,15089107	0,22949116	0,00023503	5,8053E-12	,
	N	22	38	22	42	42	42
MOTIV_C	Correlation (Pearson)	0,08856149	-0,1382477	0,17663058	0,10936473	-0,051774	-0,187906
	bidirectional Significance	0,69512129	0,56106806	0,43167789	0,6193724	0,81900932	0,40236317
	N	22	20	22	23	22	22
NUMPROJE	Correlation (Pearson)	-0,1625296	0,00887717	0,04783421	0,0655861	-0,1745174	-0,0203753
	bidirectional Significance	0,56276784	0,96793378	0,86557293	0,73534793	0,38396261	0,91965075
	N	15	23	15	29	27	27
PROJECTB	Correlation (Pearson)	0,21212212	-0,2405566	0,01672472	0,10759426	0,31507402	**0,36721445**
	bidirectional Significance	0,34327722	0,15758151	0,9411125	0,5202435	0,05750699	0,0275848
	N	22	36	22	38	37	36
PROJECTD	Correlation (Pearson)	0,30234347	0,04908452	-0,1227497	**0,33489826**	**0,41213592**	**0,54741883**
	bidirectional Significance	0,16085617	0,7729673	0,57686146	0,03465705	0,00913225	0,00037524
	N	23	37	23	40	39	38
NOVELRES	Correlation (Pearson)	0,2350931	0,07615532	-0,1507259	**0,39608963**	**0,53282901**	**0,44182803**
	bidirectional Significance	0,2802238	0,64495183	0,49240876	0,00855599	0,00033521	0,00431372
	N	23	39	23	43	41	40
ORIENTAT	Correlation (Pearson)	**-0,604792**	0,03371822	-0,3890477	-0,1348673	-0,1124984	-0,1769402
	bidirectional Significance	0,00223469	0,836362	0,06653342	0,38274404	0,47812164	0,26842675
	N	23	40	23	44	42	41
BENEFICI	Correlation (Pearson)	0,22052954	-0,0922938	0,24055744	0,01837389	0,1522944	0,19742367
	bidirectional Significance	0,31193897	0,5869271	0,26886844	0,91040224	0,35468039	0,23480025
	N	23	37	23	40	39	38

(Table 15 continued)

		MOTIV_C	NUMPROJE	PROJECTB	PROJECTD	NOVELRES	ORIENTAT	BENEFICI
PARTALLC	Correlation (Pearson)	-0,07242	**0,645863**	-0,17314	-0,05363	-0,12884	0,214994	-0,16213
	bidirectional Significance	0,742643	0,000116	0,298565	0,742395	0,404545	0,156107	0,317554
	N	23	30	38	40	44	45	40
PARTNERP	Correlation (Pearson)	-0,16023	**0,702971**	-0,25324	-0,09305	-0,05963	0,149193	-0,18456
	bidirectional Significance	0,465207	1,48E-05	0,125015	0,567949	0,700603	0,328002	0,254251
	N	23	30	38	40	44	45	40
PARTINVO	Correlation (Pearson)	-0,32569	**0,61863**	-0,28715	-0,09739	-0,08997	0,137478	-0,24543
	bidirectional Significance	0,129375	0,000269	0,080461	0,549928	0,561372	0,367819	0,1269
	N	23	30	38	40	44	45	40
RDCOMPL	Correlation (Pearson)	0,088561	-0,16253	0,212122	0,302343	0,235093	**-0,60479**	0,22053
	bidirectional Significance	0,695121	0,562768	0,343277	0,160856	0,280224	0,002235	0,311939
	N	22	15	22	23	23	23	23
COORDFUN	Correlation (Pearson)	-0,13825	0,008877	-0,24056	0,049085	0,076155	0,033718	-0,09229
	bidirectional Significance	0,561068	0,967934	0,157582	0,772967	0,644952	0,836362	0,586927
	N	20	23	36	37	39	40	37
ACTIVDIV	Correlation (Pearson)	0,176631	0,047834	0,016725	-0,12275	-0,15073	-0,38905	0,240557
	bidirectional Significance	0,431678	0,865573	0,941113	0,576861	0,492409	0,066533	0,268868
	N	22	15	22	23	23	23	23
COORDMAN	Correlation (Pearson)	0,109365	0,065586	0,107594	**0,334898**	**0,39609**	-0,13487	0,018374
	bidirectional Significance	0,619372	0,735348	0,520243	0,034657	0,008556	0,382744	0,910402
	N	23	29	38	40	43	44	40
COORDMA0	Correlation (Pearson)	-0,05177	-0,17452	0,315074	**0,412136**	**0,532829**	-0,1125	0,152294
	bidirectional Significance	0,819009	0,383963	0,057507	0,009132	0,000335	0,478122	0,35468
	N	22	27	37	39	41	42	39
COORDMA1	Correlation (Pearson)	-0,18791	-0,02038	**0,367214**	**0,547419**	**0,441828**	-0,17694	0,197424
	bidirectional Significance	0,402363	0,919651	0,027585	0,000375	0,004314	0,268427	0,2348
	N	22	27	36	38	40	41	38
MOTIV_C	Correlation (Pearson)	1	-0,17029	-0,15229	-0,13683	0,218002	-0,03904	0,066565
	bidirectional Significance	,	0,544003	0,498674	0,533576	0,317658	0,859633	0,762831
	N	23	15	22	23	23	23	23
NUMPROJE	Correlation (Pearson)	-0,17029	1	-0,15015	0,050896	-0,13344	-0,01351	-0,19972
	bidirectional Significance	0,544003	,	0,504806	0,813291	0,506978	0,945613	0,349445
	N	15	30	22	24	27	28	24
PROJECTB	Correlation (Pearson)	-0,15229	-0,15015	1	0,217227	0,21547	**-0,34653**	**0,730295**
	bidirectional Significance	0,498674	0,504806	,	0,190177	0,193875	0,033062	1,95E-07
	N	22	22	38	38	38	38	38
PROJECTD	Correlation (Pearson)	-0,13683	0,050896	0,217227	1	**0,365124**	**-0,36563**	0,031252
	bidirectional Significance	0,533576	0,813291	0,190177	,	0,02228	0,020336	0,848184
	N	23	24	38	40	39	40	40
NOVELRES	Correlation (Pearson)	0,218002	-0,13344	0,21547	**0,365124**	1	-0,18496	0,078471
	bidirectional Significance	0,317658	0,506978	0,193875	0,02228	,	0,229378	0,634903
	N	23	27	38	39	44	44	39
ORIENTAT	Correlation (Pearson)	-0,03904	-0,01351	**-0,34653**	**-0,36563**	-0,18496	1	-0,23348
	bidirectional Significance	0,859633	0,945613	0,033062	0,020336	0,229378	,	0,147063
	N	23	28	38	40	44	45	40
BENEFICI	Correlation (Pearson)	0,066565	-0,19972	**0,730295**	0,031252	0,078471	-0,23348	1
	bidirectional Significance	0,762831	0,349445	1,95E-07	0,848184	0,634903	0,147063	,
	N	23	24	38	40	39	40	40

5 OLS Regression Results

Here, we show the results of the OLS regressions presented in section 6.5 of the Final Report.

Table 16: Regression results for CM achievement related to addressing socio-technological challenges (A1_socio)

	non- standardized coefficient		standardized coefficient	T	significance
	B	standard error	Beta		
(constant)	-0,909	0,435		-2,089	0,044
NUMPART	0,010	0,011	0,153	0,928	0,360
ORIENTAT	**0,316**	**0,106**	**0,395**	**2,970**	**0,006**
COORDMAN	**0,157**	**0,081**	**0,262**	**1,945**	**0,060**
PARTNERP	**0,019**	**0,009**	**0,281**	**2,017**	**0,052**
CALLBUDG	0,000	0,000	0,237	1,687	0,101
COORDFUN	0,000	0,000	0,184	1,138	0,263
		corrected r2: 0.382, N=40			

Table 17: Regression results for CM achievement related to addressing scientific challenges (A1_scien)

	non- standardized coefficient		standardized coefficient	T	significance
	B	standard error	Beta		
(constant)	0,137	0,148		0,923	0,361
NUMPART	0,005	0,007	0,088	0,671	0,506
NOVELRES	**0,217**	**0,099**	**0,281**	**2,195**	**0,034**
PARTNERP	**0,026**	**0,007**	**0,484**	**3,750**	**0,001**
AVBUDGET	0,000	0,000	0,195	1,499	0,142
		corrected r2: 0.311, N=44			

Table 18: Regression results for CM achievement related to securing competencies for defensive reasons (A1_defen)

	non- standardized coefficient		standardized coefficient	T	significance
	B	standard error	Beta		
(constant)	-0,086	0,219		-0,393	0,697
NUMPART	-0,002	0,007	-0,041	-0,341	0,735
PARTNERP	**0,024**	**0,007**	**0,458**	**3,614**	**0,001**
CALLBUDG	0,000	0,000	0,141	1,073	0,290
COORDMAN	**0,149**	**0,065**	**0,290**	**2,305**	**0,026**
		corrected r2: 0.351, N=46			

Table 19: Regression results for CM achievement related to securing competencies for prospective reasons (A1_prosp)

	non- standardized coefficient		standardized coefficient	T	significance
	B	standard error	Beta		
(constant)	0,060	0,105		0,576	0,568
CALLBUDG	0,000	0,000	0,153	1,226	0,228
NOVELRES	0,076	0,088	0,105	0,871	0,389
PARTNERP	**0,027**	**0,006**	**0,534**	**4,314**	**0,000**
DIVERS5	**0,374**	**0,174**	**0,259**	**2,147**	**0,038**
	corrected r2: 0.400, N=44				

Table 20: Regression results for CM achievement related to reaching excellence (A1_excel)

	non- standardized coefficient		standardized coefficient	T	significance
	B	standard error	Beta		
(constant)	0,005	0,103		0,051	0,960
NOVELRES	0,093	0,086	0,132	1,073	0,290
PARTNERP	**0,027**	**0,006**	**0,557**	**4,405**	**0,000**
CALLBUDG	0,000	0,000	0,100	0,784	0,438
DIVERS5	**0,306**	**0,171**	**0,220**	**1,785**	**0,082**
	corrected r2: 0.374, N=44				

Table 21: Regression results for CM achievement related to reaching self-sustained dynamics (A1_selfs)

	non- standardized coefficient		standardized coefficient	T	significance
	B	standard error	Beta		
(constant)	-0,431	0,331		-1,301	0,204
DIVERS5	**0,681**	**0,230**	**0,403**	**2,960**	**0,006**
COORDMAN	0,054	0,075	0,095	0,724	0,475
NUMPART	0,011	0,009	0,215	1,249	0,221
PARTNERP	**0,019**	**0,007**	**0,361**	**2,524**	**0,017**
COORDFUN	**0,000**	**0,000**	**0,270**	**1,713**	**0,097**
BENEFICI	**-0,023**	**0,011**	**-0,287**	**-2,027**	**0,052**
	corrected r2: 0.451, N=36				

6 Bibliography

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