Working Paper Sustainability and Innovation
No. S 14/2018

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The Globalisation of Corporate R&D. Evidence from German Environmental Technology Companies

Fraunhofer
ISI

Abstract

This paper contributes to the discussion about the globalization of corporate R&D by analyzing R&D strategies of environmental technology companies. Data is generated from a survey among German applicants for environmental technology patents. The survey elucidates motives and functions of foreign R&D as well as factors influencing the strategic choice between domestic and foreign R&D.

The results strongly support the validity of the efficiency seeking motive for foreign R&D. Similarly, there is weak evidence for the resource seeking motive when controlling for specific host countries. In contrast, the market seeking motive had no significant influence on the intention to conduct foreign R&D in the future. Company size seems to be positively associated with investment in foreign R&D, whereas R&D intensity is not.

Keywords: Foreign R&D, Environmental Technology, Globalization of Technology

Acknowledgements: This work was supported by funding from the German Federal Ministry of Research and Education under grant number 16I1648. The author is grateful to Valentin Kölzer, Jeannette Braun and Dr. Johannes Schuler for their support.

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1 Introduction

This paper builds on the literature on the globalization of R&D and technology (Carlsson 2006) to analyze foreign R&D strategies of German companies active in the field of environmental technology. The extant literature points to the increasing relevance of international corporate networks for technology development (Cantwell und Santangelo 2000; Howells 2008; Reger 2002) and suggests, that foreign R&D can improve the adaptation of technologies to local and regional markets (Karlsson 2006) and facilitate the combination of knowledge from different scientific and cultural backgrounds (Berry 2014). Moreover, the UNCTAD (2005) has pointed out, that the globalization of corporate R&D can strengthen innovative capabilities of host countries through knowledge flows from multinationals to the local innovation system.

This strategies of environmental technology companies towards foreign R&D are of particular interest to the debate about sustainable development, because continued innovation in the field of environmental technology and enhanced global technology diffusion can help to alleviate some of the most urgent environmental problems (Gallagher 2014). Even though the rapid economic development of China, India and other Asian countries has led to significant changes during the past two decades, global technological capabilities in the field of environmental technology continue to be highly concentrated on countries of the Triade - North America, Europe and Japan (Gandenberger und Wurst 2016). In contrast, environmental problems frequently have an international or even global dimension and will require more international cooperation in the field of technology transfer as, for example, claimed by Articles 10 and 11 of the UNFCCC's Paris Agreement. In this context, Foreign R&D can be considered as a specific form of Foreign Direct Investment (FDI) and as one among various channels for global technology diffusion (Keller 2004).

This paper contributes to the discussion about international transfer of environmental technologies by analyzing foreign R&D strategies of German environmental technology companies. Data is generated from a survey among German applicants for environmental technology patents. The survey elucidates motives und purposes of foreign R&D and addresses factors influencing the strategic choice between domestic and foreign R&D. The remainder of the paper is structured as follows: Section 2 discusses findings of the literature on the globalization of corporate R&D. Section 3 describes the methodology for generating the data set. Section 4 reports descriptive statistics and results of the econometric analysis. Section 5 discusses these results and concludes.

2 Theoretical Background

Compared to many other corporate activities, R&D is still one of the least internationalized (Berry 2014) and has long been considered a case of "non globalization" (Patel und Pavitt 1991). However, this situation has started to change in recent years and the globalization of corporate R&D has become an important trend (Reger 2002, UNCTAD 2005). In this context, globalization refers to a process "when internationalisation has deepened to include a large number of countries worldwide and when the process has become increasingly detached from a particular home country...(Karlsson 2006, S. 63)." According to Howells (2008), there are three important drivers for the globalization of R&D:

- The number of countries involved in the process has increased. Whereas in the past, investment in foreign R&D has mainly taken place between countries of the Triade, now there are investment flows from advanced economies to developing countries, in particular to China and India, and vice versa;
- Companies face increasing competitive pressure to search for low cost solutions for corporate R&D;
- Companies see the need to move their R&D closer to fast growing markets in emerging economies.

In addition, rapid advances in information and communication technologies and more flexible organizational forms have greatly facilitated collaboration in global R&D networks (Cantwell und Santangelo 2000; Branstetter et al. 2018). Besides, the increase of foreign R&D is associated with the rise of international mergers and acquisitions (Karlsson 2006).

These changes in the business environment certainly contribute to a better understanding of the recent rise in foreign R&D. However, firm-internal motives need to be considered as well. When applying insights of the literature on Foreign Direct Investment (FDI) to the specific case of investment in foreign R&D (Dunning 1998), the following motives can be discerned:

- Market seeking or demand oriented foreign R&D is conducted to satisfy the needs of a specific market and to adapt existing products and processes to local conditions. In many cases, R&D is following production abroad and supports production activities based on the exploitation of existing technological competencies. The market seeking motive for foreign R&D is at the core of the so-called 'internalisation theory' of foreign R&D, which has long been considered the dominant explanation for foreign R&D (Le Bas und Sierra 2002) and has been substantiated empirically by several studies, e.g. Warrant (1991), Hirschey and Caves (1981), and Mansfield et al. (1979).

- Resource seeking or supply oriented FDI aims to improve access to the resources of a country in order to augment existing capabilities with complementary external assets (Langlois 1992). National Innovation Systems with their specific strengths and technological specialization patterns (Furman et al. 2002) can constitute such a resource. By locating R&D in countries with excellent technological capabilities, companies can establish links to local scientific networks and gain access to scientific and technological talent (Florida 1997).

  Lewin et al. (2009) demonstrate empirically that the shortage of science and engineering talent in the USA is associated with innovation offshoring. Kuemmerle (1999) finds that a country's relative market size and strength of science base determine the inflow of foreign R&D.
- Strategic asset seeking FDI wants to promote or protect the existing ownership specific advantages of the investing firm in relation to its competitors. Foreign R&D and the combination of dispersed knowledge located in global R&D networks can contribute to the build-up of a hard to imitate competitive advantage (Kogut und Zander 1992).
- Efficiency seeking FDI has the objective to bring about a more efficient division of labour within the MNC. With respect to foreign R&D, the efficiency seeking argument is closely associated with investments in emerging economies with high technological capabilities but comparatively lower wages (Howells 2008).

In light of these heterogeneous motives, it becomes clear that foreign R&D can fulfill very different functions in corporate innovation processes: The market seeking argument emphasizes the need to adapt and tailor existing products to foreign markets and hence, is associated with an incremental and application-oriented type of innovation (Rugman 1981). In contrast, the resource seeking argument is rather geared towards developing new-to-the-world, radical innovation based on improved access to scientific talent and networks. The strategic asset seeking argument broadens this perspective again by stressing the ability of MNC to combine complementary technological capabilities located in different countries.

How are these findings related to the literature dealing with environmental innovation and environmental technology? For one thing, environmental innovation is considered to be particularly challenging, because it faces the so-called double externality problem (Rennings 2000; Jaffe et al. 2005). Just like other types of technological innovation, environmental innovation produces positive knowledge externalities, which result from the public-good nature of knowledge. In addition, environmental innovation per definition generates positive externalities for the environment. Hence, the conventional wisdom is that private investments in environmental innovation will be smaller than socially desired. Moreover, environmental innovations frequently fail to move from niche to mass markets due to institutional and technological lock-ins (Unruh 2002). In order to overcome these challenges, specific environmental and technology policies are considered to be necessary (Jaffe et al. 2005; Rodrik 2015).

In face of these specific characteristics of environmental technologies paired with their increasing global relevance, the internationalization of R&D for environmental technologies has started to attract attention from research (Hansen et al. 2016; Noailly und Ryfisch 2015). Noailly and Ryfisch (2015) find that 17% of green patents result from R&D investments outside the companies home country. According to their results, the probability of conducting foreign R&D increases with the host country's stringency of environmental regulation, market size and green R&D intensity. In addition, lower wages for researchers and protection of intellectual property rights in the host country have a positive influence on the inflow of green R&D.

In order to prepare and structure the empirical research conducted in this paper, the following suppositions will derive implications of the above-mentioned characteristics of environmental innovation for the strength of different motives for foreign R&D. First, due to the higher uncertainty associated with environmental innovation, companies might make extra efforts to reduce costs and risks associated with the innovation process. This argument would support the **efficiency seeking** motive for foreign R&D. Second, the global dimension of many environmental problems, the international diffusion of environmental policies (Jänicke 2005) and the signing of transnational agreements supporting international technology transfer, have created a large market potential for environmental technology, which companies can better tap into when adapting their products and services to local needs. Hence, the **market seeking** argument seems to be particularly relevant in this context. Third, environmental technologies in general have been classified as medium to high technology goods and most of the sectors traditionally involved in the production of environmental technologies, in particular machine building, are not characterized by high investments in R&D. In view of the fact, that environmental technology and machine building in particular can be considered a traditional strength of the German innovation system, the **resource seeking** argument for foreign R&D might apply to a lesser extent.

In the following, these suppositions will be examined on the basis of data generated by a survey among German environmental technology companies.

3 Data Set and Questionnaire

The sample was generated from a population of 2425 companies registered in Germany and with at least one transnational or domestic patent application in the field of environmental technology during 2006 and 2011. In a first step, patents were identified as environmental technology based on the European CEPA/CReMA classification scheme (see Annex I for details) and a translation of these categories into IPC (International Patent Classification) codes.

Based on these IPC codes the PATSTAT database was searched for transnational and domestic patents applications in the period 2006 to 2011 of companies registered in Germany. In a second step, the patent data was matched with the Bisnode company database in order to gain additional information about the patent applicants, such as company size, sector and address. In a third step, a questionnaire in German language was sent to the head of R&D, or alternatively to the company's CEO if the company lacked such a position, in written form in April 2017. In total, 224 companies returned the questionnaire during May and June 2017, which yielded a response rate of 9.2%. A comparison of sample distribution in terms of company size and sector with the population is displayed in Table 1 and Table 2.

Table 1: Distribution of Company Size in Sample and Population, company size measured in number of employees

Employees	N Population	Percent Population	N Sample	Percent Sample
1 -50	773	32%	72	32%
51 - 100	306	13%	29	13%
101 - 250	444	18%	47	21%
251 - 500	274	11%	19	8%
501 - 1.000	194	8%	18	8%
1.001 - 5.000	224	9%	23	10%
>5.000	78	3%	14	6%
NA	132	5%	2	1%
Total	**2425**	**100%**	**224**	**100%**

Table 2: Distribution of Sectors in Sample and Population

Sector	N Population	Percent Population	N Sample	Percent Sample
Machine Building	552	23%	60	27%
Metals	218	9%	32	14%
Electrical and Optical Eq.	205	8%	19	8%
Electrical Eq.	187	8%	20	9%
Rubber and Plastic	147	6%	23	10%
Other	1116	46%	66	29%
NA	0	0%	4	2%
Total	**2425**	**100%**	**224**	**100%**

In terms of company size, the sample represents the population quite well, but the sector distribution is slightly biased towards the sectors 'machine building', 'manufacture of fabricated metals' and 'manufacture of rubber and plastic products'. The cross sectoral character of environmental technology becomes apparent in the magnitude of the 'Other' classification, which contains 46 % of the companies in the population and 29 % in the sample. Other includes sectors such as, the automotive industry, engineering offices or manufacture of glass and ceramics.

The questionnaire consists of 12 questions, thereof five are concerned with basic characteristics of the company (sector, number of employees, percentage of workforce working abroad, R&D intensity, share of foreign R&D in total R&D budget). Another seven questions deal with the company's current and future R&D strategy in Germany and abroad. Companies without foreign R&D activities were asked to skip the questions related to foreign R&D and to move on to the last question, which gave them the possibility to provide reasons for not investing in foreign R&D.

4 Results

4.1 Descriptive Statistics

Corporate R&D intensity (RD_sales) as measured in terms of average R&D expenditures in relation to sales (between 2014-2016) had a mean value of 9.38% (N = 220) and a median value of 5.0%, which is in line with prior findings characterizing environmental technology as medium to high technology. The share of the company's foreign R&D activities in the total R&D budget was 2% or less for 75% of the respondents, which suggests that R&D in the German environmental technology sector is still predominantly conducted in the home country. However, the sample mean is 5.6% (N = 217) due to some companies with very high shares of R&D conducted outside Germany.

In order to learn more about the companies' current R&D strategy with regard to geographic locations and partners, respondents were asked to highlight different types of organizations with whom they cooperated in the field of R&D. As Table 3 shows for Europe, which includes Germany, R&D conducted in a subsidiary accounted for one third of the answers and R&D in cooperation with universities/public research labs for almost a quarter. Slightly less frequent is R&D in cooperation with customers and suppliers. This pattern differs from R&D conducted by German companies in the USA, China, India and the rest of the world (RoW), where research conducted in subsidiaries has a much higher share in total R&D activity. In contrast, R&D conducted together with universities was less frequently mentioned. On average, R&D projects with customers (suppliers) seem to be more (less) frequent compared to the situation in Europe. For all regions, R&D together with competitors seem to be very rare.

Table 3: Combinations of Countries/Regions and R&D Partner Types[1]

Country/Region	N	Subsidiary	University	Customer	Supplier	Competitor
Europe	577	33%	24%	22%	18%	2%
USA	53	42%	8%	36%	13%	2%
China	64	48%	8%	20%	23%	0%
India	23	65%	4%	26%	4%	0%
RoW	72	42%	8%	36%	13%	1%

Using a five-point Likert type scale, respondents were asked to indicate their expectations towards their company's level of R&D activity in Germany and abroad

1 Multiple answers were possible.

during the next five years. The positive mean value of 0.45 (N=214) on a scale between -2 (significant decrease) and 2 (significant increase) suggests that respondents tend to slightly increase their R&D activities in Germany. With regard to foreign R&D, the mean value of 0.77 (N=112) indicates that respondents' support for increasing foreign R&D seems to be somewhat stronger than for increasing R&D in Germany (see Table 4).

Table 4: Expectations with regard to the Future Investments in Foreign R&D (FUT_Foreign_R&D) and Domestic R&D (FUT_R&D Germany)

	FUT_Foreign R&D		FUT_R&D_Germany	
	N	Percent	N	Percent
significant decrease	1	0.9%	8	3.7%
slight decrease	3	2.7%	11	5.1%
constant	38	33.9%	91	42.5%
slight increase	49	43.8%	85	39.7%
significant increase	21	18.8%	19	8.9%
Total	**112**	**100%**	**214**	**100%**

In the next question, respondents indicated the countries where they would like to conduct R&D in the future. The results revealed that European Countries are the most important destinations of German companies' foreign R&D (37.3% of the mentions), followed by China (19.3%), the USA (17.6%), India (9.8%), Japan (5.3%), and South-Korea (2.5%).

In order to gain a better understanding of the factors that motivate foreign R&D location, the next question asked respondents to what extent they agreed with the following motives:

- Proximity to production sites (Prox_Prod),
- Proximity to important suppliers (Prox_Supply),
- Proximity to fast growing markets and customers (Prox_Market),
- Proximity to important innovations systems (IS), networks or so-called 'Centers of Excellence' (Prox_Excellence),
- Cost advantages (Costs),
- Foreign R&D entity as result of corporate Merger & Acquisition (M&A) (Acquisition).

In this and the following questions, a five point Likert type scale is employed, in which a value of 0 indicates "does not apply at all" and a value of four "does fully apply". The results summarised in Table 5 point to the importance of conducting R&D close to important markets and customers (Mean = 2.98). Furthermore, proximity to production is another important argument (Mean = 2.28), which however is rejected by about one third of the respondents. Presumably, this is because these companies are not engaged in production activities. Costs (Mean = 1.77), Proximity to Centers of Excellence (Mean = 1.69), and Proximity to Suppliers (Mean = 1.64) are slightly less important and Acquisitions (Mean = 0.67) hardly applied.

Foreign R&D can serve different functions in the company's innovation process. Thus, respondents were asked to indicate, which of the following functions their foreign R&D fulfilled:

- Support of a foreign production site (Support_Prod);
- Adaptation of existing products or services to local context and market (Adaptation);
- Development of products 'new to the world' (Product_Dev);
- Development of services 'new to the world' (Service_Dev).

The results displayed in Table 5 suggest that foreign R&D is most relevant for the adaptation of existing products to the local context and market environment, but to a somewhat lesser extent also for the support of foreign production sites and the development of new products. In contrast, the development of new services seem to be less crucial for the respondents.

Table 5: Motives and Functions of Foreign R&D, scale running from 0 ("does not apply") to 4 ("fully applies")

	N	Mean	SD
Motives			
Proximity to Production	103	2.28	1.8
Proximity to Supply	100	1.64	1.42
Proximity to Market	109	2.98	1.21
Proximity to Centers of Excellence	96	1.69	1.36
Costs	96	1.77	1.38
Acquisition	93	0.67	1.15
Functions			
Support Production Site	106	2.28	1.65
Adaptation of Product / Service	107	2.79	1.26
Product Development (New-to-the-World)	110	2.11	1.3
Service Development (New-to-the-World)	100	1.25	1.19

The last two questions deal with competitive advantages and disadvantages associated with foreign R&D. Building on insight of the extant literature, the following potential advantages and disadvantages of foreign R&D were included in the survey.

Advantages associated with of foreign R&D:

- Increased innovation capacity by tapping into the strengths of foreign innovation systems;
- Improved consideration of local and regional conditions in the innovation process;
- Reduced R&D expenditures;
- Increased innovation capacity through integration of perspectives from diverse cultural and scientific backgrounds.

Disadvantages associated with foreign R&D:

- Unintended dissipation of knowledge;
- Violation of intellectual property rights;
- High investment needs;
- High operating costs;
- Large cultural distance;
- Higher uncertainty about added value compared to domestic R&D.

Please note, that the number of respondents was considerably higher for the question related to competitive disadvantages because those companies, which currently do not have foreign R&D units were asked to use this last question to indicate the most important reasons for not investing in foreign R&D. The results indicate that market advantage finds the highest approval followed by integration advantage, innovation advantage and cost advantage. With regard to potential disadvantages, knowledge dissipation was the most prominent risk, followed by IPR risks, high operating costs, uncertain value added of foreign R&D, cultural differences, and high investment needs.

Table 6: Potential Competitive Advantages and Disadvantages of Foreign R&D, scale running from 0 ("does not apply") to 4 ("fully applies")

	N	Mean	SD
Advantages			
Access to Strengths of Foreign IS	107	1.99	1.2
Improved Adaptation to Local Conditions	112	2.74	1.21
Reduced R&D Costs	107	1.78	1.31
Integration of Different Scientific Backgrounds	106	2.17	1.17
Disadvantages			
Risk of Knowledge Dissipation	191	2.58	1.05
Violation of IPR	188	2.3	1.1
High Investment Needs	185	1.78	1.06
High Operating Costs	185	2.24	1.03
Cultural Distance	181	1.94	1
Uncertain Value Added	179	2.03	1.1

4.2 Regression Results

Five ordered logistic regression models were computed to explain the expected future level of foreign R&D. The six motives for foreign R&D discussed in section 4.1 were included as explanatory variables. Furthermore, company size and R&D intensity are included as control variables. The results of the first model (I) suggest, that perceived cost advantages of foreign R&D were positively associated with foreign R&D at the $p < 0.01$ level, whereas the other motives had no significant influence on the dependent variable. Furthermore, company size was found to be positively associated with foreign R&D at the $p < 0.05$ level, but R&D intensity was not associated with foreign R&D. In addition, three regression models (II-IV) were calculated, which include specific dummy variables for China (Model II), the US (Model III) and the EU (Model IV). These Dummies were designed based on the respondents' answers to the question whether they would invest in R&D in these countries in the next five years. The models including country specific dummy variables revealed that perceived cost advantages had a highly significant positive influence on foreign R&D. In addition, 'Proximity to Centers of Excellence' had a significant ($p < 0.10$) and positive influence on foreign R&D. The results of model V, which includes all three Dummy-Variables supports these findings.

Table 7: Results of Ordered Logistic Regression Models, explaining the Future Level of Foreign R&D (FUT_FOREIGN_RD)

	I	II	III	IV	V
	b/SE	**b/SE**	**b/SE**	**b/SE**	**b/SE**
Prox_Prod	-0.269	-0.194	-0.206	-0.2	-0.198
	0.18	*0.18*	*0.18*	*0.18*	*0.18*
Prox_Supply	-0.039	-0.022	-0.019	-0.005	0.016
	0.17	*0.17*	*0.17*	*0.17*	*0.18*
Prox_Market	0.147	0.186	0.164	0.14	0.154
	0.23	*0.23*	*0.23*	*0.23*	*0.23*
Prox_Excellence	0.269	0.334*	0.331*	0.353*	0.362*
	0.19	*0.19*	*0.19*	*0.19*	*0.19*
Costs	0.653***	0.587**	0.574***	0.556***	0.598***
	0.2	*0.21*	*0.2*	*0.2*	*0.22*
Acquisition	-0.233	-0.293	-0.29	-0.22	-0.244
	0.22	*0.22*	*0.22*	*0.23*	*0.24*
Size	0.309**	0.197	0.192	0.201	0.204
	0.15	*0.13*	*0.13*	*0.13*	*0.13*
RD_SALES	0.022				
	0.02				
CN_Dummy		-0.117			-0.234
		0.54			*0.56*
USA_Dummy			0.134		0.13
			0.48		*0.48*
EU_Dummy				-0.332	-0.369
				0.5	*0.51*
N	78	79	79	79	79
Log Likelihood	-80.221	-82.65	-82.63	-82.45	-82.34
Chi-Square	20.04**	17.51**	17.54**	17.91**	18.13*
Pseudo R2	0.111	0.096	0.096	0.098	0.099

Notes: *Significance at p < 0.1, **Significance at p < 0.05, ***Significance at p < 0.01, Standard Errors in italics

5 Discussion & Conclusions

The regression results strongly support the validity of the **efficiency seeking** motive for foreign R&D of German environmental technology companies, which supports the argument put forward in section 2. Similarly, there is weak evidence for the **resource seeking** motive, when country specific dummy variables for the EU, China and the USA are included in the model. In contrast to the considerations in section 2, the **market seeking** motive seems to have no significant influence on the intention to conduct foreign R&D. Moreover, company size (as measured in number of employees) seems to be positively associated with investments in foreign R&D, whereas R&D intensity is not.

These results correspond with prior research of Noailly and Ryfisch (2015) in the sense that a wage differential of science and engineering personnel increases the likelihood of environmental technology companies to invest in foreign R&D. Unlike other prior studies, the results do not support the market seeking motive for foreign R&D. A possible explanation might be that MNC, which have started to invest in foreign R&D in the past, might initially have focused on product adaptation and are now in a position to involve their foreign R&D units from the beginning of the innovation process, making product adaptation at later stages of the innovation process redundant. Therefore, in recent years, the emphasis might have shifted towards realizing cost reductions. Future research is necessary to shed light on this finding. The weak evidence for the resource seeking argument is again in line with Noailly and Ryfisch (2015) and many other prior studies (e.g. Florida 1997), but somewhat in contrast to the assumptions of section 2, stating that Germany's industrial strength in environmental technology and machine building would weaken the relevance of the resource seeking motive. Nevertheless, one has to keep in mind that the environmental technology is a cross cutting technology field, which makes it very likely that other countries have developed unique technological capabilities (Walz et al. 2008), which are complementary to those in Germany.

The positive impact of company size on foreign R&D activity supports the intuition that larger companies have a wider geographic reach and are therefore more likely to invest in foreign R&D. Unlike other prior surveys (e.g. UNCTAD 2005), the survey was not focused on large MNC. Hence, only half of the companies in the sample stated that they conduct foreign R&D and on average, foreign R&D seems to be only a small fraction of corporate R&D budgets. Important barriers to conduct foreign R&D seem to be rooted on the risk of unintended knowledge dissipation and the risk of IPR violation, which is in accordance with prior studies

(Branstetter et al. 2006; Lai 1998). Compared with R&D in the EU context, foreign R&D conducted in a non-EU context is focused on R&D in subsidiaries, whereas R&D together with universities is much less frequent.

Taken together, these findings suggest that German environmental technology companies tend to expand their foreign R&D primarily in order to reduce the costs associated with environmental innovation. At the same time, German companies use this strategy to tap into the complementary strengths of larger foreign innovation systems.

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7 Appendix

Appendix 1: CEPA/CReMA-Classification

CEPA	Classification of Environmental Protection Activities	CReMA	Classification of Resource Management Activities
1	Protection of ambient air and climate	10	Management of waters
2	Wastewater management	11	Management of forest resources
3	Waste management	11 A	Management of forest areas
4	Protection and remediation of soil, groundwater and surface water	11 B	Minimisation of the intake of forest resources
5	Noise and vibration abatement	12	Management of wild flora and fauna
6	Protection of biodiversity and landscape	13	Management of energy resources
7	Protection against radiation	13 A	Production of energy from renewable sources
8	Research and development	13 B	Heat/energy saving and management
9	Other environmental protection activities	13 C	Minimization of the intake of fossil resources as raw materials for uses other than energy production
		14	Management of minerals
		15	Research and development
		16	Other natural resource management activities

Source: Eurostat (2009)

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Karlsruhe 2018