Assessing companies' capability to develop advanced manufacturing technologies in selected industrial sectors

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1 Introduction

The context of this study is to provide empirical evidence on the role of innovation in Advanced Manufacturing Technologies (AMT) and Key Enabling Technologies (KETs) at the firm level. The aim is to assess efficiency and productivity as well as employment effects of R&D expenditure and innovation investment within AMT and KETs. The main task hereby is to link the innovation output of companies with its input in terms of R&D expenditures and analyze this data with respect to the policy implications at the level of the EU member states as well as third countries, especially the US and Japan. The data source for the input is the "EU Industrial R&D Investment Scoreboard" (henceforth *Scoreboard* or *R&D Scoreboard*) and the output are patent applications and further patent related indicators at the transnational level. Patents are mainly an output of technology oriented R&D activities in technology-based sectors (Freeman 1982; Grupp 1998). It is thus meaningful to assess the linkage of input and output with the help of R&D and patents in technology-based areas.

Advanced Manufacturing Technologies and Key Enabling Technologies are core areas for achieving the strategic goals addressed in EU 2020. A number of products and initiatives are already underway in this respect, which this project can rely on. These are for example the technology definitions in terms of classes of the International Patent Classification (IPC) of KETs and AMT that have been developed within the course of the "KETs Observatory" project (IDEA Consult et al. 2012). We also apply these definitions in order to generate comparable and consistent results. Our focus, however, is the firm-level as well as the relation of inputs into innovative activities and its outputs in terms of patent applications. The basic questions that we address are: Who are the firms that are responsible for most of the patent filings in AMT and KETs and which are the main industrial sectors responsible for patent filings within the two technology fields? Where have the inventions been made (where has the R&D been carried out)? Which countries and which sectors are most actively inventing AMT and KETs? Who owns the technologies or how does the ownership structure within AMT and KETs look like?

Our focus will be on transnational patent filings (Frietsch and Schmoch 2010), i.e. filings targeting international markets. Besides making use of the applicant information contained in patent filings, we will additionally make use of the inventor information in order to find out where the inventors are located (in terms of countries and sectors) that are most actively inventing KETs and AMT technologies. With regard to the question of ownership, we will take a detailed look at the headquarter location of the companies contained in the R&D Scoreboard data.

To be able to analyze technological output of industrial sectors in AMT and KETs, assess the relation of R&D expenditures (input) to patent filings (output) and to take into account the information on company headquarter locations, however, we are in need of a link between the data from R&D Scoreboard and patent data. To generate this link, we apply a string matching algorithm to link the companies from the R&D Scoreboard with the data on patent applicants from the "EPO Worldwide Patent Statistical Database" (PATSTAT). Once this link is established, we can make use of the combined information contained in both datasets, i.e. we are able to relate companies' inventive inputs (R&D expenditures contained in the R&D Scoreboard) to its outputs.

In the following sections, first of all the identification of relevant IPC codes for AMT and KETs is described. As already stated, we will hereby rely on the existing definitions from the "KETs Observatory". Then, some basic descriptive statistics on total patent filings in AMT and KETs, including a differentiation by country and technology fields, are provided. This so to say provides us with baseline information to which we can later relate the patent output of the largest R&D performing firms that are listed in the R&D Scoreboard. In the next step, the matching algorithm as well as its validation is described. Finally, the results of the study are presented.

2 Identification of relevant IPC codes for AMT and KETs

A central task for the assessment of companies’ capability to develop Advanced Manufacturing Technologies as well as Key Enabling Technologies in terms of patents is the definition of the fields. To stay consistent with already existing figures with regard to patenting in KETs and AMT, we resort to the most recent definition of KETs that has been developed by the KETs Observatory, where AMT is included as a KETs subfield (IDEA Consult et al. 2012). The definition is based on the International Patent Classification (IPC). The IPC 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 changes more effectively. Existing data is adjusted to the current version of the IPC, i.e. it is so to say "classified backwards" (Frietsch 2007; WIPO 2006). The KETs Observatory definition of KETs, including the six subfields, is displayed in Table 1. Some IPC classes are assigned to more than one of the KETs subfields, for example the 4-digit code "B82Y" is assigned to "nanotechnology" and the 6-

digit sub-code "B82Y 25" is assigned to "micro- and nanoelectronics". This implies that double counts of patents are possible, i.e. a patent classified as "B82Y 25" is counted once for "nanotechnology" and once for "micro- and nanoelectronics".

Table 1 KETs Observatory definition of KETs and it subfields

Nanotechnology deals with methods to analyzing, controlling and manufacturing structures on a molecular or atomic scale, i.e. of a size of 100 nanometers or less.	B82Y, B81C, B82B
Photonics relates to optical technology applications in the areas of lasers, lithography, optical measurement systems, microscopes, lenses, optical communication, digital photography, LEDs and OLEDs, displays and solar cells.	F21K, F21V, F21Y, G01D 5/26, G01D 5/58, G01D 15/14, G01G 23/32, G01J, G01L 1/24, G01L 3/08, G01L 11/02, G01L 23/06, G01M 11, G01P 3/36, G01P 3/38, G01P 3/68, G01P 5/26, G01Q 20/02, G01Q 30/02, G01Q 60/06, G01Q 60/18, G01R 15/22, G01R 15/24, G01R 23/17, G01R 31/308, G01R 33/032, G01R 33/26, G01S 7/481, G01V 8, G02B 5, G02B 6 (excluded subclasses 1, 3, 6/36, 6/38, 6/40, 6/44, 6/46), G02B 13/14, G03B 42, G03G 21/08, G06E, G06F 3/042, G06K 9/58, G06K 9/74, G06N 3/067, G08B 13/186, G08C 19/36, G08C 23/04, G08C 23/06, G08G 1/04, G11B 7/12, G11B 7/125, G11B 7/13, G11B 7/135, G11B 11/03, G11B 11/12, G11B 11/18, G11C 11/42, G11C 13/04, G11C 19/30, H01J 3, H01J 5/16, H01J 29/46, H01J 29/82, H01J 29/89, H01J 31/50, H01J 37/04, H01J 37/05, H01J 49/04, H01J 49/06, H01L 31/052, H01L 31/055, H01L 31/10, H01L 33/06, H01L 33/08, H01L 33/10, H01L 33/18, H01L 51/50, H01L 51/52, H01S 3, H01S 5, H02N 6, H05B 33
Industrial biotechnology focuses on enzymes, micro-organisms, aminoacids and fermentation processes (only patents that are not related to the fields of medicine or agriculture).	C02F 3/34, C07C 29, C07D 475, C07K 2, C08B 3, C08B 7, C08H 1, C08L 89, C09D 11, C09D 189, C09J 189, C12M, C12N, C12P, C12Q, C12S, G01N 27/327 (excluded if co-occurrence with A01, A61, C07K 14/435, C07K 14/47, C07K 14/705, C07K 16/18, C07K 16/28, C12N 15/00, C12N 15/09, C12N 15/11, C12N 15/12, C12N 5/10, C12P 21/02, C12P 21/08, C12Q 1/68, G01N 33/15, G01N 33/50, G01N 33/53, G01N 33/68, G01N 33/566)
Advanced materials can cover a broad area of innovation in materials, including polymers, macromolecular compounds, rubber, metals, glass, ceramics, other non-metallic materials and fibres as well as the whole field of nanomaterials and speciality materials for electric or magnetic applications. Focus on material innovations in the areas of layered products, compounds, allays and nanomaterials.	B32B 9, B32B 15, B32B 17, B32B 18, B32B 19, B32B 25, B32B 27, B82Y 30, C01B 31, C01D 15, C01D 17, C01F 13, C01F 15, C01F 17, C03C, C04B 35, C08F, C08J 5, C08L, C22C, C23C, D21H 17, G02B 1, H01B 3, H01F 1/0, H01F 1/12, H01F 1/34, H01F 1/42, H01F 1/44, H01L 51/30, H01L 51/46, H01L 51/54.
Micro- and nanoelectronics covers new technologies related to semiconductors, piezo-electrics and nanoelectronics.	B82Y 25, G01R 31/26, G01R 31/27 , G01R 31/28 , G01R 31/303 , G01R 31/304, G01R 31/317, G01R 31/327, G09G 3/14, G09G 3/32, H01F 1/40, H01F 10/193, H01G 9/028, H01G 9/032, H01H 47/32, H01H 57, H01L, H03B 5/32, H03C 3/22, H03F 3/04, H03F 3/06, H03F 3/08, H03F 3/10, H03F 3/12, H03F 3/14, H03F 3/16, H03F 3/183, H03F 3/21, H03F 3/343, H03F 3/387, H03F 3/55, H03K 17/72, H05K 1, H05K 3.
Advanced Manufacturing Technologies for other KETs covers process technology that is used to produce any of the other five KETs. In case of advanced materials, industrial biotechnology, nanotechnology and micro- and nanoelectronics, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials and components. In case of photonics, process technology covers apparatus and equipment that is used to manufacture photonics items.	B03C, B06B 1/6, B06B 3/00, B07C, B23H, B23K, B23P, B23Q, B25J, G01D, G01F, G01H, G01L, G01M, G01P, G01Q, G05B, G05D, G05F, G05G, G06M, G07C, G08C (excluded if co-occurrence with G01D 5/12, G05F 1/10, G07C 9/00, G01P 3/42, H01L 21/02, G05B 19/05, H05K 3/34, G01D 5/14, F02D 45/00, H01L 29/66, G05F 1/56, G05F 3/24, G07C 5/00, G05D 1/00, B60T 8/17, G05D 1/02, G01M 15/04, G01M 17/007, G07C 5/08, F02D 41/14 G05D 1/06, B60R 16/02, B62D 65/00, B60T 7/04, G01P 21/00, B60R 25/00, B62D 57/00, B60T 8/172, B60T 7/06, B62D 57/032, E05B 49/00, G01P 3/489, G05D 1/08), G06 (included if co-occurrence with A21C, A22B, A22C, A23N, A24C, A41H, A42C, A43D B01F, B02B, B02C, B03B, B03D, B05C, B05D, B07B, B08B, B21B, B21D, B21F, B21H, B21J, B22C, B23B, B23C, B23D, B23G, B24B, B24C, B25D, B26D, B26F, B27B, B27C, B27F, B27J, B28D, B30B, B31B, B31C, B31D, B31F, B41B, B41C, B41D, B41F, B41G, B41L, B41N, B42B, B42C, B44B, B65B, B65C, B65H, B67B, B67C, B68F, C14B, C23C, D01B, D01D, D01G, D01H, D02G, D02H, D02J, D03C, D03D, D03J, D04B, D04C, D05B, D05C, D06B, D06G, D06H, D21B, D21D, D21F, D21G, E01C, E02D, E02F, E21B, E21C, E21D, E21F, F04F, F16N, F26B, G01K, H05H)

Source: Based on IDEA Consult, ZEW, TNO, CEA (2012), updated version of 2014.

On top of the KETs Observatory definition, we identify five different technologies as examples of application oriented technologies that are related to KETs. These are:

- **Fuel cells:** Fuel cells promise the use of new energy sources such as hydrogen (but also biogas) and can achieve a very high degree of efficiency. The development focuses on cost-, weight- and size reduction, as well as the storage of hydrogen. For mobile applications, fuel cells with solid electrolytes or fuel cells with polymer-electrolyte-membranes (PEM) are particularly relevant, which are included in the definition.

- **Digital information transmission:** This field includes technologies for the transmission of digital information, like telegraphic communication.
- **Imaging physics:** Imaging physics includes all pictorial communication, e.g. television. It covers the transmission of pictures or their reproduction (locally or remotely) by scanning a picture – through derivation of picture-representative electric signals – resolving and reproducing it. It does not include circuits, the analysis of alphanumeric characters and direct photographic copying.
- **Dynamo-electric machines (electric motors):** Dynamo-electric machines refer to the conversion of mechanical to electrical energy or vice versa by electromagnetic means. The structural adaptation of dynamo-electric machines for the purpose of their control is covered. The assembly or installation of electric motors to vehicles as well as the monitoring of those vehicles and the regulation or control of motors, generators or dynamo-electric converters are not covered.
- **Biotechnology – Agro Food:** Agro-food is defined as micro-organisms or enzymes and their composition as well as propagating, preserving and maintaining them. It includes undifferentiated animal or plant cells and their cultivation, mutation and genetic engineering.

The definition of the respective technologies is also based on the IPC. They have been developed with technology experts at Fraunhofer ISI.

3 Data and methods

In this section, the data used for the study are described. On the one hand, this is the EU R&D Scoreboard containing company-specific data on, amongst others, R&D expenditures. On the other hand, these are the patent data used for the study based on the "EPO Worldwide Patent Statistical Database" (PATSTAT).

3.1 The patent data

The patent data for the study were extracted from the "EPO Worldwide Patent Statistical Database" (PATSTAT). PATSTAT is a relational database with more than 28 tables and millions of entries that can be installed on a local server that is self administrated. It covers information about published patents from 83 patent authorities worldwide, dating back to the late 19th century.

The database is updated twice a year, implying that analyses of the most recent data are possible. PATSTAT includes all information that is stated on a patent application, i.e. application authorities (patent offices), several patent relevant dates (priority-, filing-, publication date), the kind of an application (patent, utility models, etc.), inventor and applicant addresses, patent families (INPADOC and DOCDB), patent classifications (IPC and ECLA), title and abstract of a patent filing, technical relations and continuations, citations to patents and to non-patent literature as well as – in a supplemented version of PATSTAT – information on the legal status of a patent application (grants, withdrawals, refusals, maintenance) from the PRS (Patent Register Service) data file of the EPO.

Within the original version of PATSTAT, the names of the applicants still are in a "raw version" taken directly from the patent application, which means that several variants of the same patent applicant name exist. The applicant name also contains special characters, abbreviations, legal forms, and spelling mistakes. The automated harmonization of all occurring applicant names in PATSTAT developed by the K.U. Leuven solves this problem (Du Plessis et al. 2009; Magerman T. et al. 2009; Peeters B. et al. 2009). The name harmonization includes a cleaning of special characters (HTML code, accents, etc.), a punctuation cleaning, a cleaning of legal forms (e.g. Inc., Ltd., GmbH), the harmonization of additional enterprise information ("COMPANY", "CORP", "CORPORATION"), a harmonization of spelling variants ("SYSTEM", "SYSTEMS", "SYSTEMES"), the condensation of irrelevant characters ("3 COM", "3COM") and an umlaut harmonization. This means that patents can be more exactly assigned as belonging to a specific patent applicant, which minimizes classification errors to a large extent.

The patents in our analyses are counted according to their year of worldwide first filing, which is commonly known as the priority year. This is the earliest registered date in the patent process and is therefore closest to the date of invention. As patents are in this report – first and foremost – seen as an output of R&D processes, using this relation between invention and filing seems appropriate. At the core of the analysis, the data applied here follows a concept suggested by Frietsch and Schmoch (2010), which is able to overcome the home advantage of domestic applicants, so that a comparison of technological strengths and weaknesses becomes possible – beyond home advantages and unequal market orientations. In detail, all PCT applications are counted, whether transferred to the EPO or not, and all direct EPO applications without precursor PCT application. Double counting of transferred Euro-PCT applications is thereby excluded. Simply speaking, all patent families with at least a PCT application or an EPO application are taken into account.

The data from the PATSTAT database was matched at the level of patent applicants in the harmonized version with data from the R&D Scoreboard at the level of individual companies (including subsidiaries). The matching procedure will be discussed in more detail below.

3.2 The EU Industrial R&D Investment Scoreboard

This description of the EU Industrial R&D Investment Scoreboard was kindly supplied by Petros Gkotsis from the JRC-IPTS and slightly adapted by the authors to fit this report.

The *Scoreboard* is part of the European Commission's monitoring activities to improve the understanding of trends in R&D investment by the private sector and the factors affecting it. It was created in response to the Commission's Research Investment Action Plan[1], which aims to help close the gap between the EU's R&D investment and that of other developed economies.

The annual publication of the *Scoreboard* is intended to raise awareness of the importance of R&D for businesses and to encourage firms to disclose information about their R&D investments and other intangible assets.

The data for the *Scoreboard* are taken from the publicly available audited accounts of the companies. As in more than 99% of cases these accounts do not include information on the place where R&D is actually performed, the company's whole R&D investment in the *Scoreboard* is attributed to the country in which it has its registered office[2]. This should be borne in mind when interpreting the *Scoreboard*'s country classifications and analyses.

1 "Investing in research: an action plan for Europe", COM(2003)266, http://europa.eu.int/eur-lex/en/com/cnc/2003/com2003_0226en02.pdf.

2 The registered office is the company address notified to the official company registry. It is normally the place where a company's books are kept.

The *Scoreboard*'s approach is, therefore, fundamentally different[3] from that of statistical offices or the OECD when preparing Business Enterprise Expenditure on R&D (BERD) data, which are specific to a given territory. The *Scoreboard* data are primarily of interest to those concerned with benchmarking company commitments and performance (e.g. companies, investors and policymakers), while BERD data are primarily used by economists, governments and international organizations interested in the R&D performance of territorial units defined by political boundaries. The two approaches are therefore complementary.

In 2013, implementing changes in the "EU Industrial R&D Investment Scoreboard" (the *Scoreboard*)[4] aiming to enhance its capacity to monitor and analyze worldwide trends of industrial R&D was continued.

The scope of the *Scoreboard* is improved progressively, increasing the geographic and time coverage and the number of companies. The target is to cover the world's top 2500 R&D investors so that further faster growing middle-sized companies can be captured, particularly those in key sectors such as health and the ICT-related industries.

Thus far, the total R&D investment of companies included in the *Scoreboard* is equivalent to almost 90% of the total expenditure on R&D by businesses worldwide[5].

The 2013 edition of the *Scoreboard* includes the 2000 companies investing the largest sums in R&D in the world while maintaining an EU focus by complementing this coverage including the top 1000 R&D investing companies based in the EU.

The *Scoreboard* collects key information to enable the R&D and economic performance of companies to be assessed. The main indicators, namely R&D investment, net sales,

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3 The *Scoreboard* refers to all R&D financed by a company from its own funds, regardless of where the R&D is performed. BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of finance. The sources of data also differ: the *Scoreboard* collects data from audited financial accounts and reports whereas BERD typically takes a stratified sample, covering all large companies and a representative sample of smaller companies. Additional differences concern the definition of R&D intensity (BERD uses the percentage of R&D in value added, while the *Scoreboard* considers the R&D/Sales ratio) and the sectoral classification (BERD uses NACE (the European statistical classification of economic sectors), while the *Scoreboard* uses the ICB (the International Classification Benchmark).

4 The EU Industrial R&D Investment Scoreboard is published annually by the European Commission (JRC-IPTS/DG RTD) as part of its Industrial Research Monitoring and Analysis activity (IRMA). Company data were collected.

5 According to latest figures reported by Eurostat, i.e. BERD financed by the business enterprise sector in 2009 compared with R&D figures in the 2010 Scoreboard.

capital expenditures, operating profits and number of employees are collected following the same methodologies, definitions and assumptions applied in earlier years. This ensures comparability so that the companies' economic and financial data can be analyzed over a longer period of time.

For the second year, data are now being collected by (Bureau van Dijk Electronic Publishing GmbH) following basically the same approach and methodology applied since the first *Scoreboard* edition.

The capacity of data collection is being improved by gathering information about the ownership structure of the *Scoreboard* parent companies and the main indicators for their subsidiaries. This allows a better characterization of companies, in particular regarding the sectoral and geographic distribution of their research and production activities and the related patterns of growth and employment.

Companies' behavior and performance can be analyzed over longer time periods using the database that contains information on the top R&D companies since 2003. This enables benchmarking analyses of companies across sectors and countries, in order for example to identify companies showing outstanding economic or innovation results and to analyze the main factors underlying such successful dynamics.

In the 2013 edition of the *Scoreboard*, companies' R&D rankings are based on information taken from the companies' latest published accounts. For most companies these correspond to calendar year 2012, but a significant proportion have financial years ending on 31 March 2013. There are few companies included with financial years ending as late as end June 2013 and a few for which only accounts to end 2011 were available.

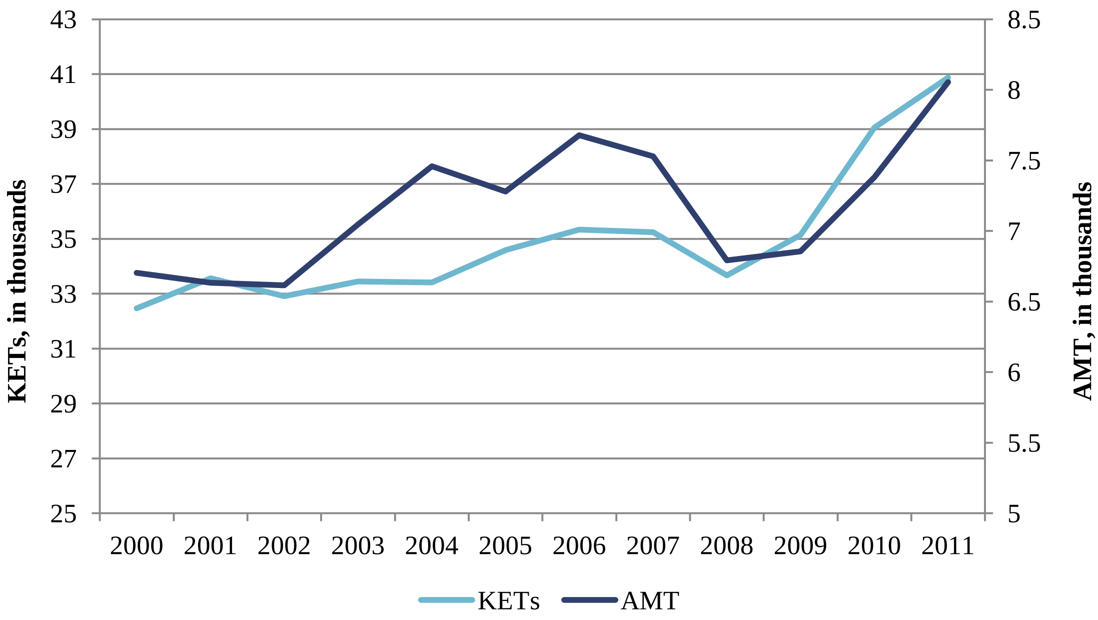
4 Trends in KETs and AMT patenting

In this section, some general structures and patenting trends within KETs and AMT are presented. The focus here is the total amount of transnational patent filings within the two technology fields to get a general overview of the worldwide patent activities. Besides providing the more general picture in patent activities, this also can be used as a reference frame against which the firms of the R&D Scoreboard can later be compared. In addition to the general trends in filings numbers, we will differentiate the statistics by (applicant) countries and technology fields.

4.1 General trends

In Figure 1, the number of transnational patent filings in KETs and AMT over time is plotted. The general trends are similar in both fields, although at different levels. In the year 2000, about 32,000 transnational KETs patents were filed. This number increased to about 35,000 in 2007 but then decreased between 2008 and 2009. This, however, is a general trend triggered by the economic crisis that is also visible in total patent filings. From 2009 onwards, the number of filings in KETs has risen very rapidly up to about 41,000 filings in 2011. For AMT technologies, 6,600 transnational filings in the year 2000 can be found. Once again, we observe a growth phase until 2006/2007 and a steep decline in 2008. However, also in AMT, the growth rate, at least from 2009 onwards, is very high, leading to about 8,000 transnational filings in 2011.

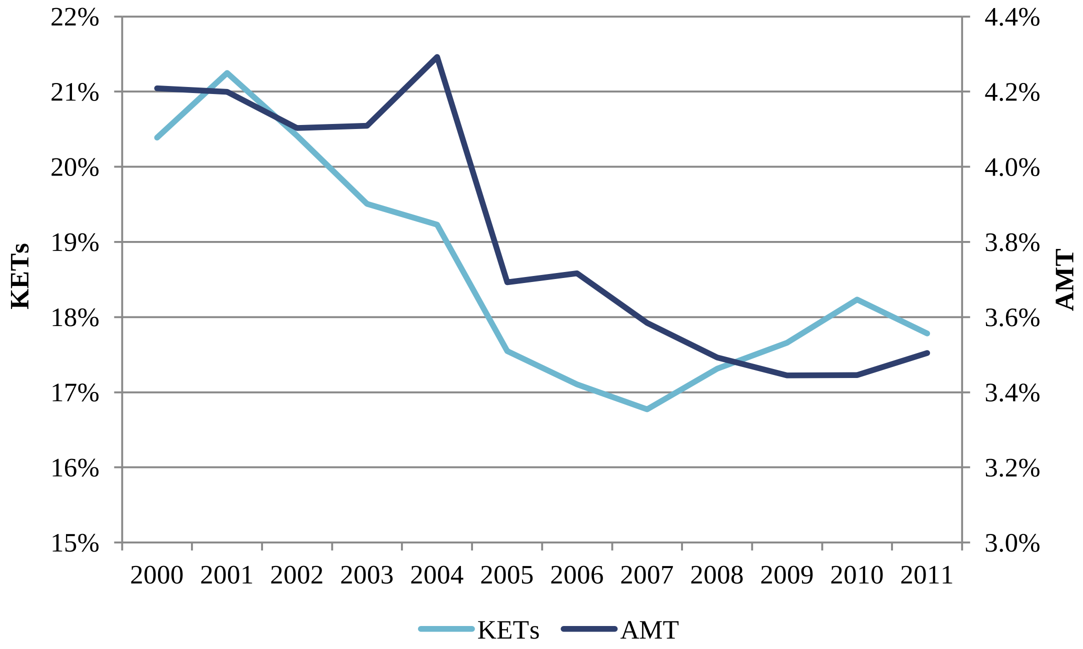
Figure 1 Number of transnational patent filings in KETs and AMT



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

The share of KETs and AMT in total transnational filings is plotted in Figure 2. Although the absolute numbers of patent filings in KETs and AMT have increased, the shares of KETs and AMT filings have decreased in both technology fields. This is due to the fact that the total number of filings is rising rather constantly, implying that the number of KETs and AMT filings have grown below average in the last decade. Whereas in 2000 the share of KETs filings in total filings amounted to 20%, it decreased to 18% in the year 2011. Similarly for AMT, where a share of 4.2% in total filings could be observed in 2000, we find a decrease to 3.5% in 2011. This overall trend, however, was reversed with the steep increase of the AMT and especially the KETs filings of the recent years.

Figure 2 Shares of KETs and AMT in total filings, transnational



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Table 2 presents the Top 20 worldwide patent applicants in KETs and AMT. With regard to KETs, two Japanese firms, namely *Panasonic* and *Sharp* are on top of the list with more than 2,000 transnational patent filings between 2009 and 2011. They are followed by the German *Siemens AG* and the Japanese *Fujifilm Corp.* with each about 1,200 filings. On rank five, Philips with slightly above 1,000 transnational patent filings between 2009 and 2011 can be found. In general, it can be observed that the list of top applicants in KETs is dominated by Japanese firms, i.e. nine out of twenty companies are located in Japan.

In AMT, the top applicant list is led by two German companies, namely the *Siemens AG* and the *Robert Bosch GmbH*, with 765 and 447 transnational filings, respectively. The two German firms are followed by the US based *General Electric* and *Mitsubishi Electric* as well as *Panasonic* from Japan.

Table 2 Top 20 patent applicants in KETs and AMT, transnational filings, 2009-2011

KETs

Country of the applicant	Applicant name	# filings
JP	PANASONIC CORP	2240
JP	SHARP KK	2166
DE	SIEMENS AG	1194
JP	FUJIFILM CORP	1182
NL	KONINKL PHILIPS ELECTRONICS NV	1021
KR	LG INNOTEK CO LTD	866
US	APPLIED MATERIALS INC	847
DE	BOSCH GMBH ROBERT	837
JP	SUMITOMO CHEMICAL CO	806
DE	BASF SE	742
US	GEN ELECTRIC	734
FR	COMMISSARIAT ENERGIE ATOMIQUE	670
US	3M INNOVATIVE PROPERTIES CO	629
US	DU PONT	623
JP	NITTO DENKO CORP	610
JP	ASAHI GLASS CO LTD	553
JP	MITSUBISHI ELECTRIC CORP	551
JP	SUMITOMO ELECTRIC INDUSTRIES	538
JP	TOKYO ELECTRON LTD	522
JP	CANON KK	518

AMT

Country of the applicant	Applicant name	# filings
DE	SIEMENS AG	765
DE	BOSCH GMBH ROBERT	447
US	GEN ELECTRIC	357
JP	MITSUBISHI ELECTRIC CORP	257
JP	PANASONIC CORP	197
US	HONEYWELL INT INC	178
JP	TOYOTA MOTOR CO LTD	157
JP	MITSUBISHI HEAVY IND LTD	153
JP	HITACHI LTD	143
JP	YASKAWA DENKI SEISAKUSHO KK	139
US	ILLINOIS TOOL WORKS	131
JP	HONDA MOTOR CO LTD	117
CH	ABB RESEARCH LTD	110
FR	COMMISSARIAT ENERGIE ATOMIQUE	110
US	BOEING CO	109
SE	SKF AB	108
NL	KONINKL PHILIPS ELECTRONICS NV	100
DE	CONTINENTAL AUTOMOTIVE GMBH	88
JP	OMRON TATEISI ELECTRONICS CO	82
JP	KOBE STEEL LTD	82

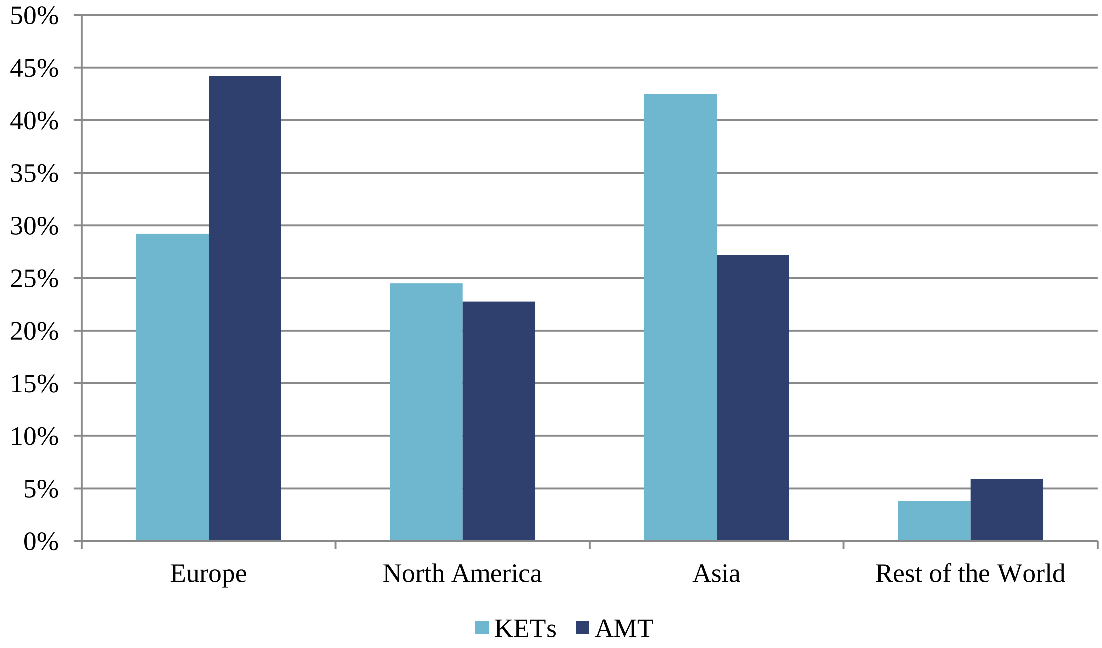
Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Note: Patent applicants marked red appear in both lists.

4.2 Country- and field specific trends

The country-specific shares in KETs filings at the transnational level are provided in Figure 3. The differentiation is performed on the basis of the patent applicant, i.e. we are looking at the question who "owns" the respective patent filings. At this aggregation level, however, the difference to analyses based on the inventor country, i.e. the country where the inventor is located, is rather small (between 1% and 2%). For a clearer visibility, the countries were categorized into four groups: Europe, North America, Asia and "Rest of the world" (Figure 3). In Figure 5, more differentiated country analyses are provided for the EU-28.

Figure 3 Country-specific shares in KETs and AMT filings, country groups, 2009-2011



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Note: Europe: EU-28, Norway, Russia, Turkey, Ukraine, Belarus, Azerbaijan, Kazakhstan, Georgia, Armenia, Turkmenistan, Tajikistan, Uzbekistan, Kyrgyzstan; North America: USA, Canada, Mexico; Asia: China, Japan, South Korea, Taiwan, India, Philippines, Thailand, Indonesia, Malaysia, Vietnam, Cambodia, Lao, Myanmar, Bhutan, Bangladesh, Pakistan, Afghanistan, Iran, Iraq, Oman, Yemen, Saudi Arabia, Kuwait, Jordan, Israel, Syria, Lebanon, Qatar, United Arab Emirates, Singapore, Hong Kong. The remaining countries were listed as belonging to the "rest of the world".

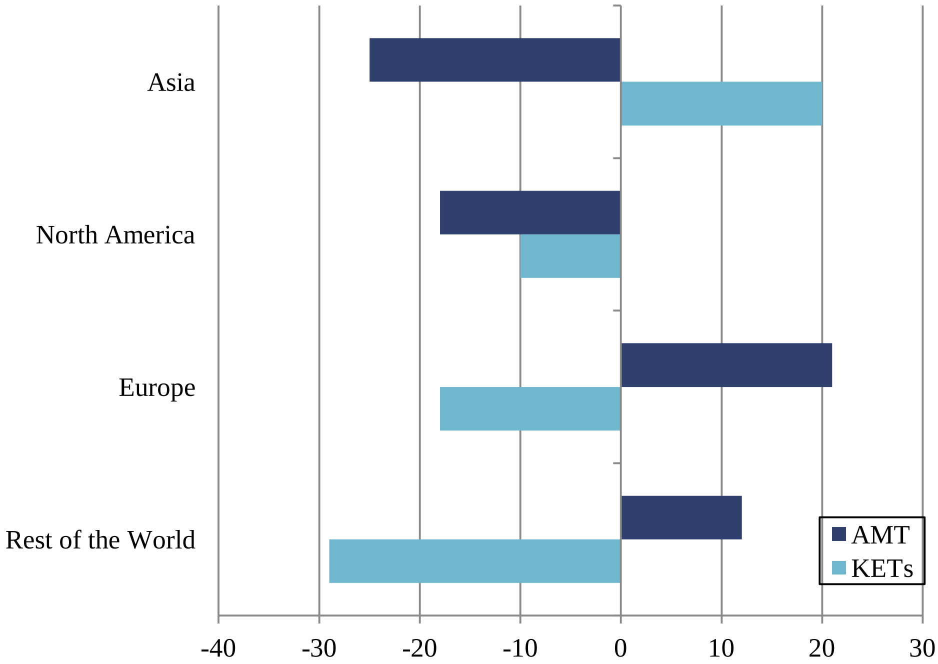
Figure 3 shows that 42% of the transnational filings within KETs originate from Asian applicants. This is in line with the results obtained from the list of top applicants (Table 2). In combination with these results, it can be stated that most of the transnational patents filed by Asian countries originate from Japanese applicants. The next largest applicant is Europe, from where 29% of all transnational KETs files are coming. North America scores third with 24% of all transnational filings. Only 4% of KETs countries come from the remaining countries all over the world. Interestingly, the picture looks totally different for AMT. Here, a clear focus on European countries can be observed. European applicants are responsible for 44% of all transnational AMT filings, followed by Asia (27%) and North America (23%). With 6%, the share of the rest of the world is slightly higher than in the case of KETs.

To compare the relative position of KETs and AMT within the technology portfolios of the country groups, patent specializations were calculated. For the analysis of specializations, the relative patent share or Reveal Patent Advantage (RPA) was estimated. It indicates in which fields a country is strongly or weakly represented compared to the total patent applications. The RPA is calculated as follows:

$$RPA_{kj} = 100 * \tanh \ln [(P_{kj}/\sum_j P_{kj})/(\sum_k P_{kj}/\sum_{kj} P_{kj})]$$

where P_{kj} stands for the number of patent applications in country k in technology field j. Positive signs mean that a technology field (in this case KETs or AMT) has a higher weight within the country than in the world. Accordingly, a negative sign represents a below-average specialization.

Figure 4 Specialization profiles of the country-groups in KETs and AMT, 2009-2011

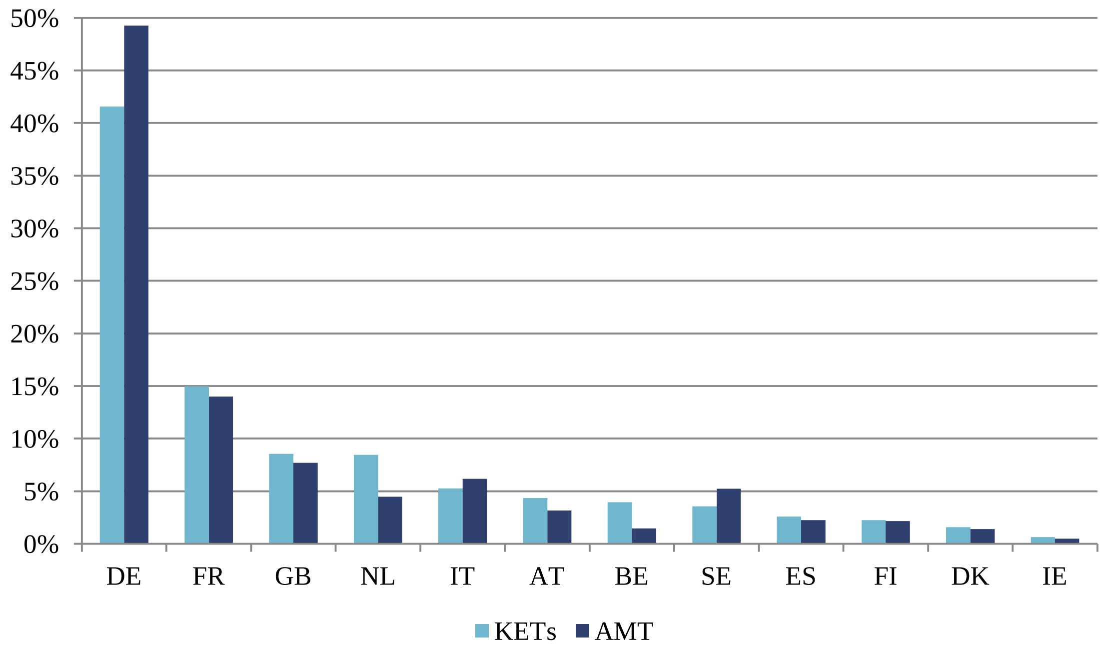


Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

The specialization profiles (Figure 4) mostly confirm the trends found before. Asia has a negative specialization in AMT, while the values are positive in KETs. This implies that Asia is more specialized in other KETs fields but not AMT. The trend is reversed for Europe. Here, a positive specialization for AMT can be found, whereas KETs in total show negative values. This is similar in the "rest of the world", although the specializations in KETS and AMT are at a lower level. North America shows negative specializations in KETs as well as AMT.

When breaking the European figures down to the member states of the EU-28, it can be observed that German applicants are responsible for 42% of all KETs filings filed by EU-28 countries. It is followed by France (15%) and Great Britain (9%). Finland (2%), Denmark (2%) and Ireland (1%) are the smallest technology providing countries in absolute terms within this comparison, while the remaining EU-28 member states have shares below 1%. A similar picture can be drawn for AMT, although the share for German applicants is even higher. Nearly 50% of all AMT filings from EU-28 member states originate from Germany, once again followed by France (14%) and Great Britain (8%). It is interesting to note that not only Germany, but also Italy and Sweden reach higher shares in AMT than in KETs in total, while all other countries in comparison, especially the Netherlands, have higher shares in KETs than in AMT.

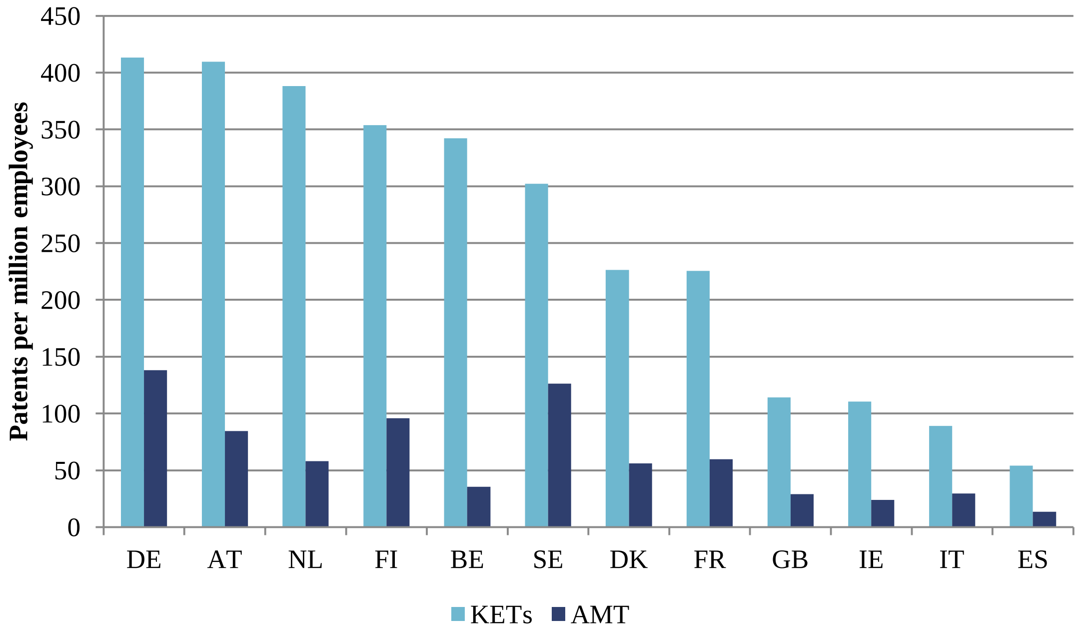
Figure 5 Country-specific shares in KETs and AMT filings within the EU-28, 2009-2011



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.
Note: Only EU-28 countries with shares in KETs and AMT filings above 1% are shown.

This picture, however, changes when looking at the transnational patent filings per million employees within the respective countries (Figure 6). These figures ensure a better international comparability since they are not influenced by the size of the workforce within the countries under analysis. Based on this indicator, we still find Germany closely up front within the EU-28 with the most KETs patent filings per million employees. Yet, in this comparison, the technological strengths of the smaller countries become visible. Germany is closely followed by Austria, the Netherlands, Finland and Belgium. France and Great Britain score on the lower ranks within this comparison. For AMT, we also find the highest number of filings per million employees for Germany, followed by Sweden, Finland and Austria. France is located in the middle with a patent intensity value of 60, i.e. 60 transnational patent filings per one million employees. Great Britain scores on the lower ranks together with Belgium, Italy, Ireland and Spain.

Figure 6 Patents per million employees in KETs and AMT by applicant country in the EU-28, 2009-2011

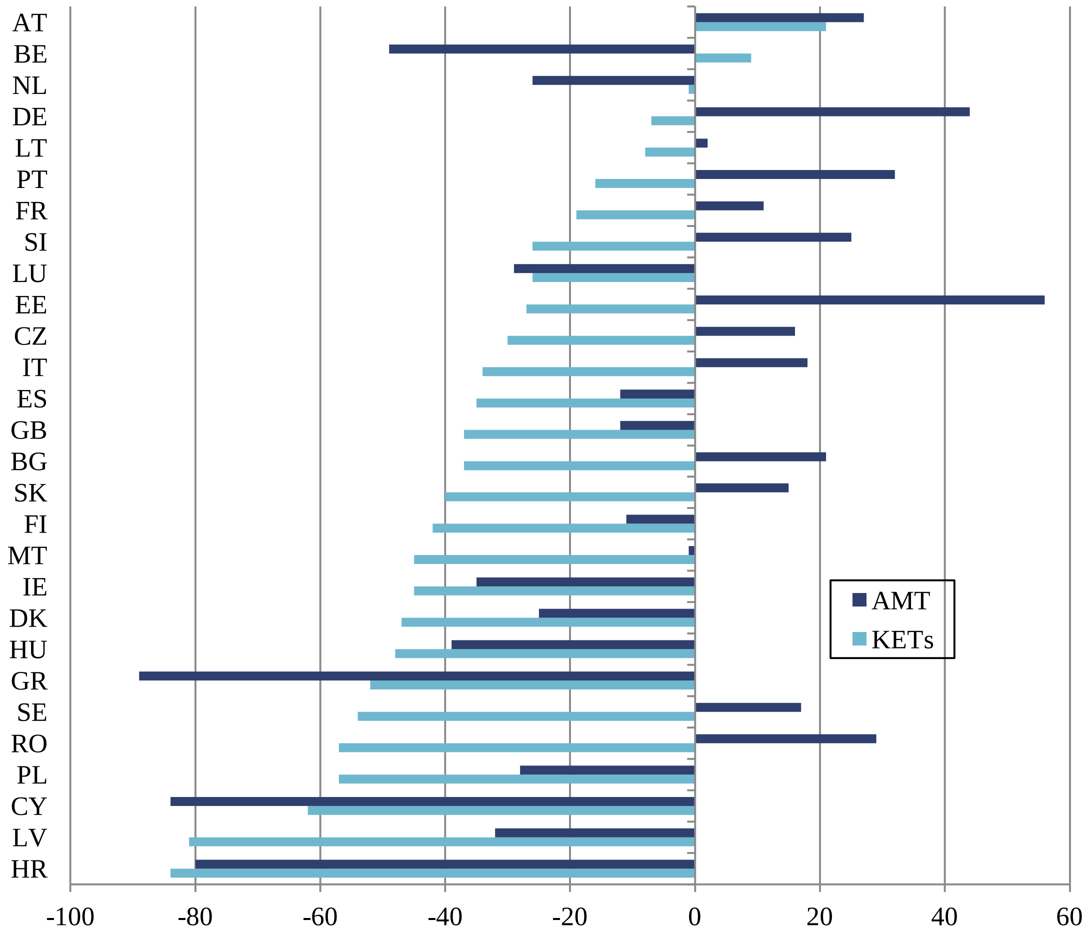


Source: EPO – PATSTAT, calculations by Fraunhofer ISI.
Note: Only EU-28 countries with shares in KETs and AMT filings above 1% are shown.

A look at the specialization values within the European countries reveals further interesting trends. With regards to KETs, positive specialization values can only be found for Austria and Belgium, implying that these are the only European countries where KETs have a higher weight within the technology portfolio than in the world. In AMT, on the other hand, there are several countries with highly positive specializations. Estonia has the strongest specialization in AMT, although it files only few patents in absolute terms. Second is Germany, followed by Portugal, Romania, Austria and Slovenia.

Most negative specializations in AMT can be observed for Greece, Cyprus, Croatia and Belgium.

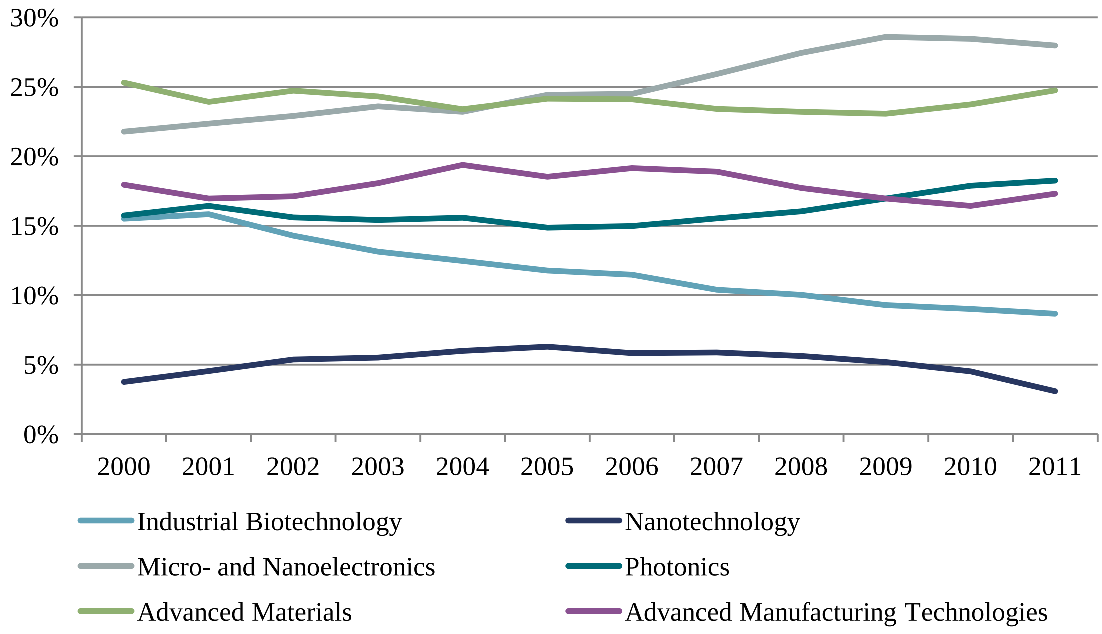
Figure 7 Specialization profiles of the countries in KETs and AMT within the EU-28, 2009-2011



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

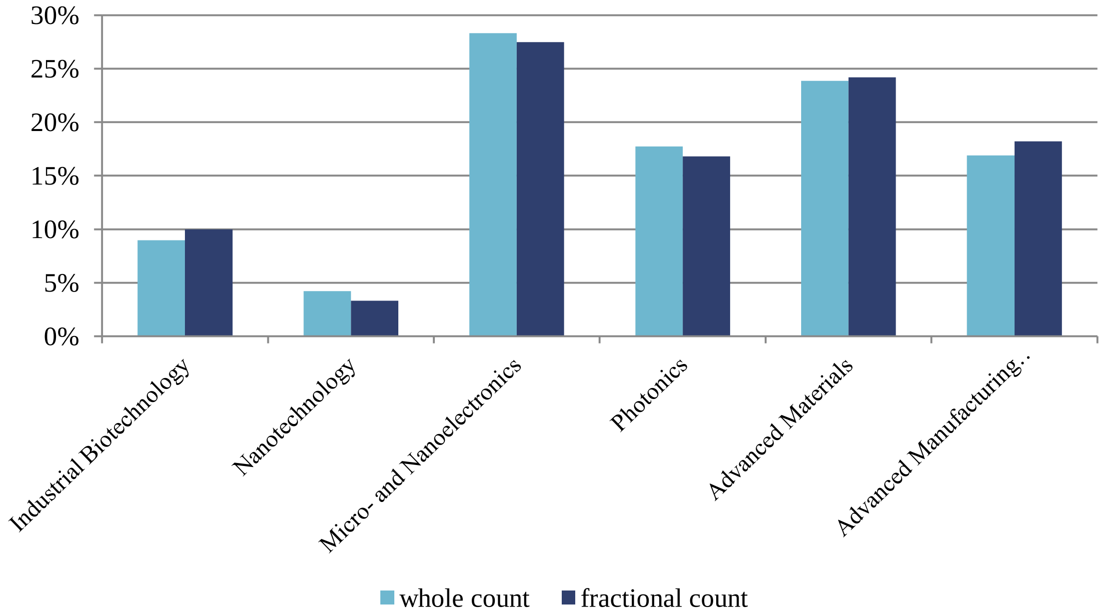
To be able to assess the relative size of AMT as a subfield of KETs in terms of patenting, KETs are differentiated alongside the subfields in Figure 8. The largest field within KETs in terms of patent filings is "micro- and nanoelectronics" (28%), followed by "advanced materials" (25%), "photonics" (18%) and "AMT" (17%). With shares around 9%, "industrial biotechnology" is the second smallest subfield, while "nanotechnology" is the smallest (3%). The shares for "AMT", "advanced materials" and "nanotechnology" are rather stable over the years. For the subfields "micro- and nanoelectronics" as well as "photonics", a relative growth can be observed from 2006 onwards, which goes along with declining shares in "industrial biotechnology" that can be observed over the whole time period.

Figure 8 Shares of KETs subfields in total transnational KETs filings



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

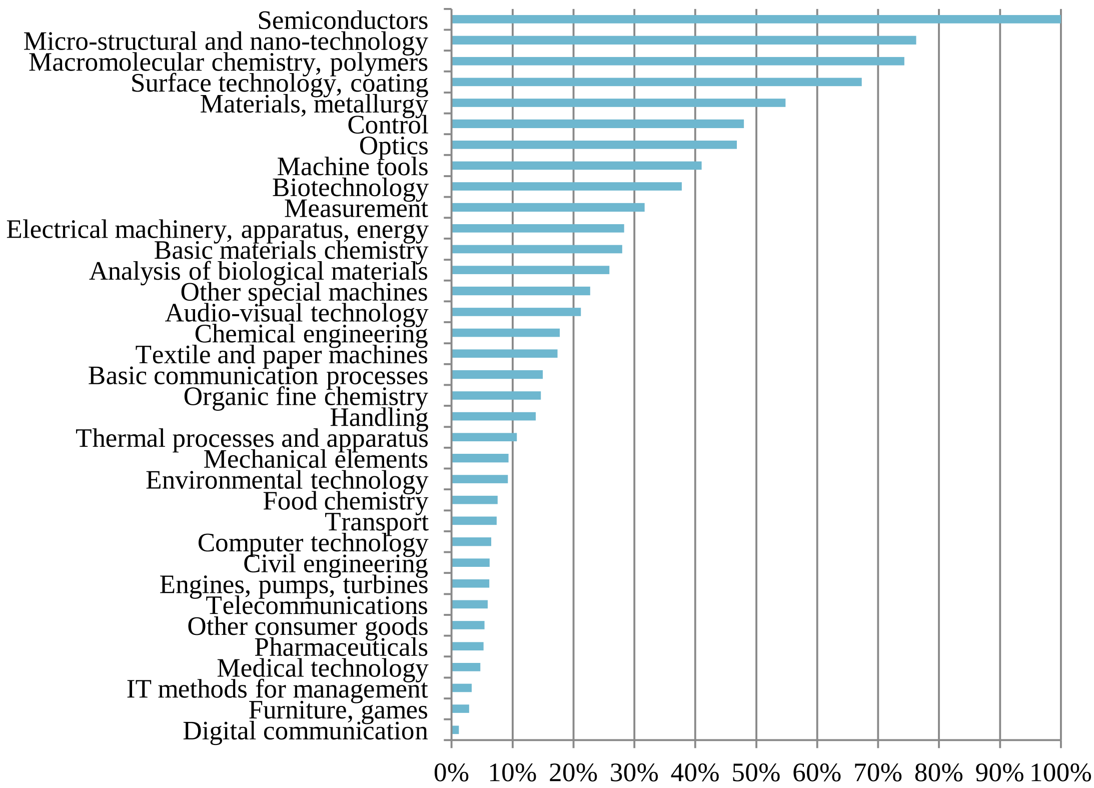
Figure 9 Shares of KETs subfields in total transnational KETs filings, whole count vs. fractional count, 2009-2011



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

As stated in section 2, double-counts of patents in more than one field within the definition of KETs are possible. This is due to multiple assignments of IPC codes to the different KETs subfields. Although this only holds for a limited number of IPC codes, Figure 9 shows the shares of KETs subfields in total transnational KETs filings for the years 2009-2011 by the "whole count" vs. the "fractional count" method. This allows assessing the influence of the double counts on the differentiation by KETs subfields. While a patent is assigned once to each field in the case of a double classification with the whole count method, it is only assigned the respective fraction with the fractional count method. For instance, if a patent is assigned to "nanotechnology" and "micro- and nanoelectronics", it would only be counted half for each of the fields. As we can see from Figure 9, however, the difference between the two methods within the KETs definition is negligible and lies below 1% across all fields. We therefore apply the whole count method for the remainder of the analyses, which eases the interpretation of the results, especially when the patent filings are differentiated by firms within the R&D Scoreboard.

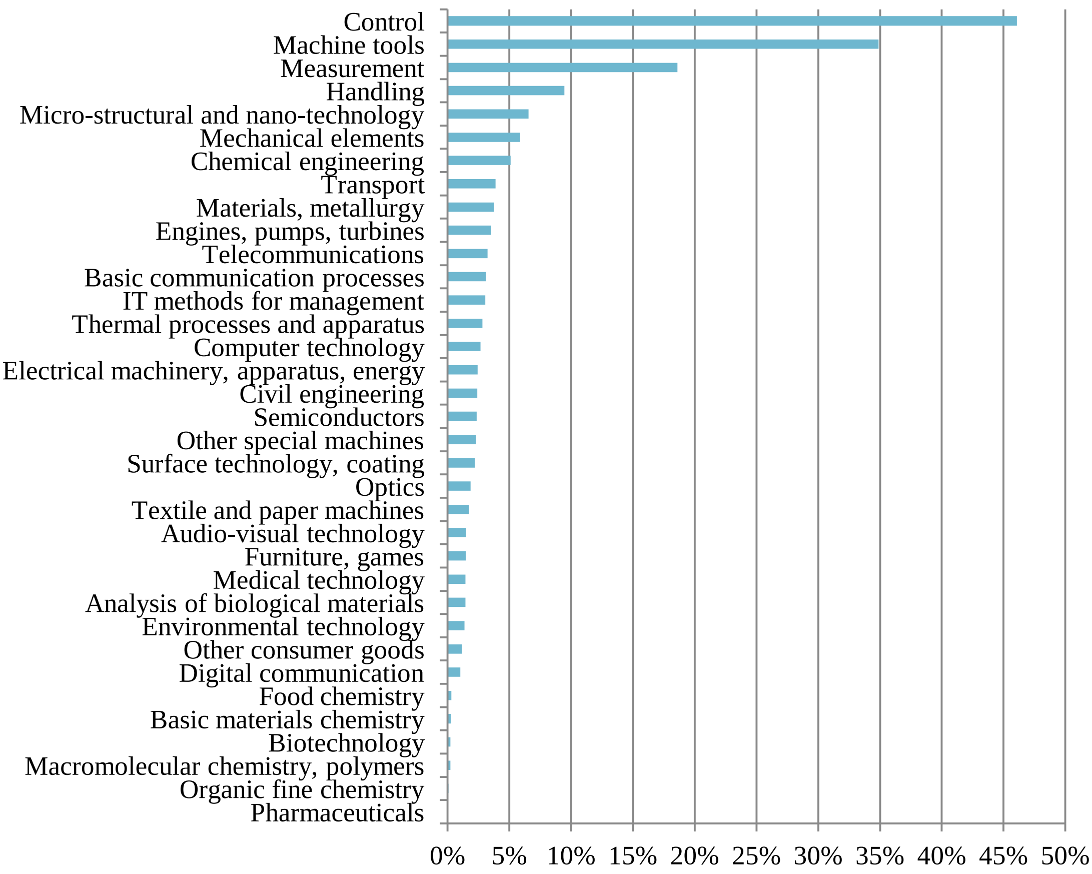
Figure 10 Share of KETs filings across technology fields, transnational, 2009-2011



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

Finally, to get a better impression of the technology fields where KETs and AMT play a major role, we differentiated the KETs and AMT filings alongside the technology field list of the 35 WIPO fields (Schmoch 2008). This is plotted in Figure 10. With the help of this graph, it is possible to assess the "spread" of KETs across technology fields. For example, 74% of all filings classified as "macromolecular chemistry, polymers" belong to the group of KETs.[6]

Figure 11 Shares of AMT filings across technology fields, transnational, 2009-2011



Source: EPO – PATSTAT, calculations by Fraunhofer ISI.

The first remarkable observation is that KETs spread across all technology fields. At least 1% of the filings in the respective field are classified as KETs. This share lies at 100% for "semiconductors", i.e. all filings in the field of "semiconductors" are assigned

6 Patents usually are assigned multiple IPC classes. The calculation shown here only provides the information whether a patent assigned an IPC class within a field of the WIPO35 definition also belongs to the IPC-based definition of KETS/AMT.

an IPC code that is also assigned to KETs, and is smallest in the field of "digital communication" (1%). The second largest share can be observed for "micro-structural and nanotechnology" (76%), followed by "macromolecular chemistry, polymers" (74%), "surface technology, coating" (67%) and "materials, metallurgy" (55%).

Since KETs covers a wide range of technologies, naturally the spread of AMT across different technology fields is far narrower than for KETs (Figure 11). The highest shares of AMT patents can be found in the fields "control", "machine tools", "measurement" and "handling". However, as can be seen in the figure, AMT patents are also filed in electronics and related fields as well as medical and environmental technologies.

5 Matching company and patent data

For the assessment of the technological output of industrial sectors in AMT and KETs as well as for the assessment of an input-output relation, a link between the R&D Scoreboard and PATSTAT is a necessary precondition. In addition, only via this link at the company/patent applicant level, a link at the level of industrial sectors (Industry Classification Benchmark, ICB) and technologies (IPC) becomes possible. Since patent data are classified by its technological implications within the IPC, a direct association to economic sectors or industries is not existent. The analysis of patents by economic sector thus requires a combination of patent data with company data at the micro-level. Based on this link, patent analyses by industries are not only possible at the company level but also at the sectoral level.

To generate the link between the two datasets, a probability matching of patent applicants with company names from the R&D Scoreboard was performed. In the 2013 Scoreboard, 2000 worldwide companies are listed for which information on subsidiaries is available. Since the scope of the *Scoreboard* is improved progressively, information on additional 847 (yet unpublished) companies (without subsidiary information) was additionally available. Therefore, the matching procedure is performed for the complete set of 2,847 companies and their subsidiaries. They are also included in the analysis on the coverage of the matching (see below). For our further analyses, however, we exclude the 847 firms without subsidiary information in order to stay consistent with the figures published in the *Scoreboard* and not to introduce a potential bias due to missing subsidiary information.

The aim of the matching procedure is to locate information on patent applicants in PATSTAT that corresponds to an entry within the company names in the R&D Scoreboard or has a high similarity with it. For this purpose, the similarity between applicant names in PATSTAT and each entry of company names in the R&D Scoreboard, including the names of the subsidiaries of these companies, was calculated. With the help of a "gold standard" dataset, i.e. a manually created match of a subset of firms, the variance in similarity values for correct matches could be determined. Particularly, a threshold value was identified that can be used to decide whether a "match" is accepted, i.e. where the similarity value is higher than the threshold. All data associated with the entry in PATSTAT can then be linked to the entry in the company database and vice versa.

In the case of name variations, name changes and the like, as well as in case of information on subsidiaries, it may happen that several PATSTAT entries are assigned to one entry within the Scoreboard list of company names. In this case, the PATSTAT entries will be treated in an aggregate form. Finally, the corresponding name pairs are stored in a separate table in the PATSTAT database for further use.

The matching procedure basically involves three steps, data cleaning, calculation of similarity scores and the selection of the matched entries. Each of these steps will be described in more detail below.

5.1 Data Cleaning

Although we already resort to a pre-cleaned patent applicant name version, a further cleaning of text-strings is the first step within the matching procedure. It is a necessary precondition for the matching so that the similarity is not unnecessarily reduced by spelling variations. The applicant names from PATSTAT as well as the company names from the R&D Scoreboard were cleaned by the same procedure to ascertain conformity.

All text strings were converted to lowercase letters and umlauts were replaced by the corresponding vowel. Special characters were replaced by a space and all occurrences of multiple spaces were replaced by a single space. In that way, we avoid incorrect assemblies of words that are only divided by a special character, particularly those separated by an “&”.

Afterwards, text strings denoting the legal form of the companies were removed. The list used to detect legal forms contains internationally applicable notations as well as country specific forms, i.e. the legal forms that are available for a given country as well as the country of the company/applicant have to be identical for the legal form to be removed. This is to circumvent the deletion of abbreviations that might have a legal meaning in one country but not in others.

Finally, country and city names were removed from the company names, however, only if they occur at the end of the company name. This is to prevent cleanings where the country information is an essential part of the company name, for example in the case of "France Telecom". For this step as the country assigned to the company/applicant was compared with the one mentioned in the text string to avoid potential errors.

5.2 Calculation of similarity scores

For the computation of the similarity scores, a variant of the Levenshtein distance was applied. The Levenshtein distance is a calculation of how many edits would be needed in order to align two text-strings. Edits can hereby mean: insertion, deletion or replacement of a character. Thus, the Levenshtein distance itself measures the dissimilarity between two text strings. For a normalized similarity measure, the result of the Levenshtein distance is divided by the number of characters of the longer of the two text strings (which corresponds to the maximum value of the Levenshtein distance for the two texts) and subtracted from 1 (the maximum similarity). In that way, the resulting similarity function is restricted to the range between 0 and 1. The lower the number of edits necessary to align two text strings, the higher the similarity between the two.

In the final procedure, only those pairs of PATSTAT and R&D Scoreboard entries that exceed a predetermined similarity threshold value "t" were selected as matches. The threshold is determined with the indicators "Recall" and "Precision" for a manually matched random dataset (N=200, 100 company names and 100 subsidiary names) as the "gold-standard". Multiple assignments of PATSTAT to R&D Scoreboard entries are allowed. These matches are then stored in a separate table in the PATSTAT database for further use.

- **Recall** or True Positive Rate: Proportion of correctly as positive identified elements in the total number of positive elements = TP/(TP+FN). How many of the “true” matches were actually found?
- **Precision** or Positive Predictive Value: Proportion of correctly as positive identified elements in the total number of elements identified as positive = TP/(TP+FP). How many of the proposed matches are correct?
- **F-Score:** Harmonic mean of Recall and Precision. Increasing the Recall usually leads to reduction of the Precision (Baeza-Yates and Ribeiro-Neto 2011; Raffo and Lhuillery 2009; van Rijsbergen 1979; Witten and Eibe 2014). F-score is hereby the optimal compromise between the two measures.

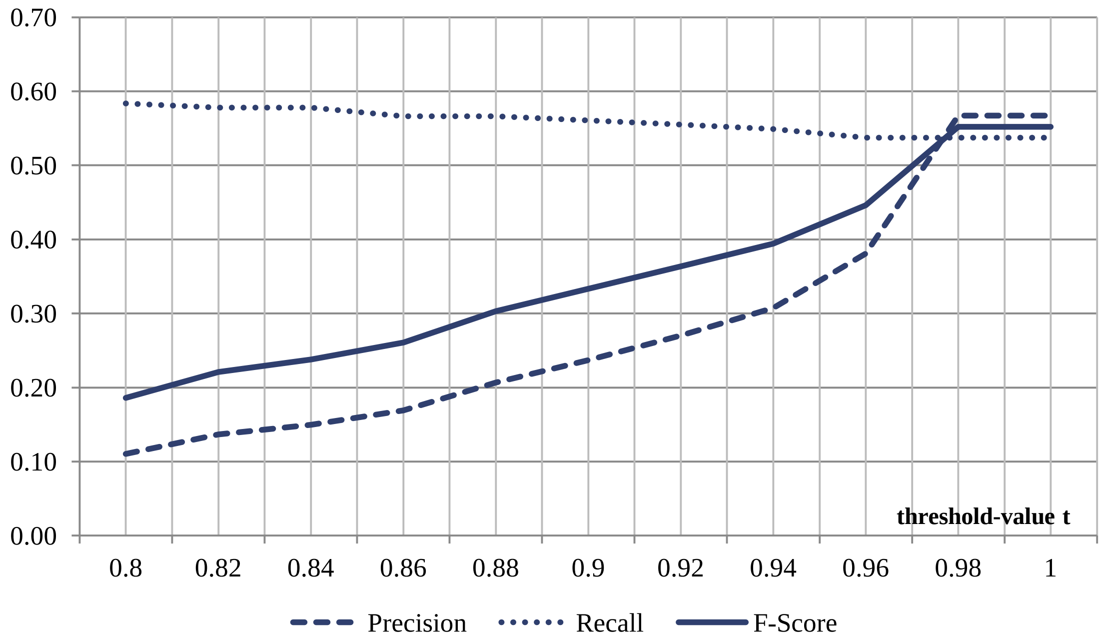
Table 3 Terminology for the calculation of Recall and Precision scores

		Condition	
		positive	negative
Matching outcome	positive	TP	FP (Type I error)
	negative	FN (Type II error)	TN

Source: Illustration by Fraunhofer ISI.

An overview about the calculated Recall, Precision and F-Score values for both matching runs at different levels of the threshold value t is provided in Figure 12. From there, we can observe that the F-Score is highest at a threshold value of t=0.98. Working with a lower threshold value would lead to a slight increase in recall, however, at the expense of a massive loss in precision. Since we work with such an extremely high threshold value, i.e. the applicant/company names in the two databases are almost equal, implying that the matches identified as such via the automated algorithm are correct in the vast majority of cases. A recall value of 0.55 at t=0.98, on the other hand, means that manual searches were necessary after the automated procedure to make sure that all patenting companies are assigned a corresponding applicant from the PATSTAT database.

Figure 12 Recall, precision and F-Score values for both matching runs at different levels of the threshold value t



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

5.3 Selection of the matched entries

For the selection of our matched pairs, we ran the matching algorithm twice. In the first step, companies as well as their subsidiaries in both datasets were matched only if they share the same country information, i.e. we included a country criterion. In case the country information was not the same, the similarity value was set to 0. For companies without country information in one or both datasets, the country criterion was not used.

In the second step, the country criterion was excluded for all companies that were not assigned a corresponding entry in the first run. This was only done for the company headquarters, i.e. without subsidiaries, which had not been matched in the first run. The second step is to prevent that some potential correct matches that were missed due to the country criterion in the first step are included. This especially applies to companies with branches in multiple countries. For example, *Alcoa Deutschland* located in Germany, would not be matched to the corresponding entry *Alcoa Inc.*, a US-based firm, in the first step. Since our aim was to collect all patent filings for all branches of a company, even if they are spread across the world, as well as its subsidiaries, the second run of the algorithm is necessary. Only by including this step, company parts in different parts of the world could be matched to the corresponding R&D Scoreboard entry, i.e. *Alcoa Deutschland* is matched to *Alcoa Inc.*, regardless of the country information.

Including the patent filings for all branches of a company including the subsidiaries also implies that we always treat companies "as a whole" in terms of patenting. For example in the case of the Magna Powertrain Verwaltungs GmbH all patents for the Magna Group as a whole, including Magna Powertrain USA, Magna International, Magna E-Car Systems, Magna BDW Technologies, Magna Automotive Services, Magna Steyr Fahrzeugtechnik, etc. are included.[7]

In sum, this procedure allows to perform a fine-grained match between patent applicants and companies from the R&D Scoreboard. The restriction to an "optimal compromise" of course at the same time implies that not all patent applicants can unambiguously be assigned to companies using the described method. Especially for large patent applicants this may mean a loss of a significant number of patent filings. For this reason, a final step included a manual search of R&D Scoreboard companies that had not been assigned to any patent applicant in PATSTAT to make sure that we do not miss impor-

7 This means that we might overestimate patent intensities per R&D expenditures in some occasions. For these analyses (see below) we will thus exclude the upper and the lower 1% as outliers.

tant information. During this procedure, also minor adjustments to the automatic assignments were made and incorrect assignments were corrected.

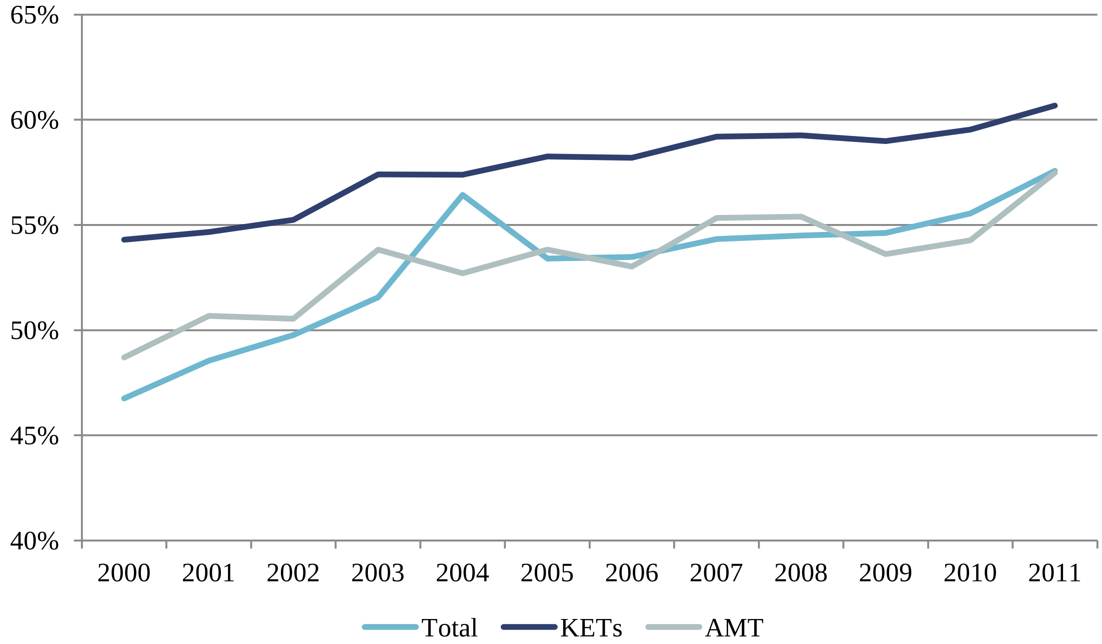
With the help of the generated firm-level dataset, also analyses at the level of industry sectors/sub-sectors as well as technology fields are possible. In addition, we were able to calculate more specific patent indicators at the company level, e.g. patent forward citations or average patent family size, which allows an assessment of the companies' patent portfolios.

5.4 Coverage of the matching

From the 2,847 firms in the R&D Scoreboard (including subsidiaries), 2,670 could be assigned a corresponding patent applicant in PATSTAT, i.e. 93% of the firms listed in the R&D Scoreboard are covered by the matching. In the first step of the matching, i.e. including the country criterion, 2,432 matches were made. Step 2, excluding the country criterion, led to 97 additional matches. With the help of the final manual searches, another 141 Scoreboard firms could be identified. The 2,670 matched Scoreboard firms correspond to a share of 58% of worldwide transnational patents filed in 2011 (see Figure 13). The remaining 42% are patents filed by universities or public research institutes, single inventors or firms that are not covered within the R&D Scoreboard, like for example "Schaeffler Technologies" or the "Yazaki Corporation". Within the fields of KETs and AMT, 61% and 57%, respectively, of all transnational patent filings are covered by the matching, i.e. the firms in the R&D Scoreboard are responsible for 61% of all transnational KETs filings in 2011 (57% in AMT). Since we apply the list of company names from the R&D Scoreboard of 2012, the coverage in the earlier years is somewhat lower than in the more recent years, i.e. the universe of worldwide firms is in constant change resulting in a lower coverage when performing analyses in earlier years.

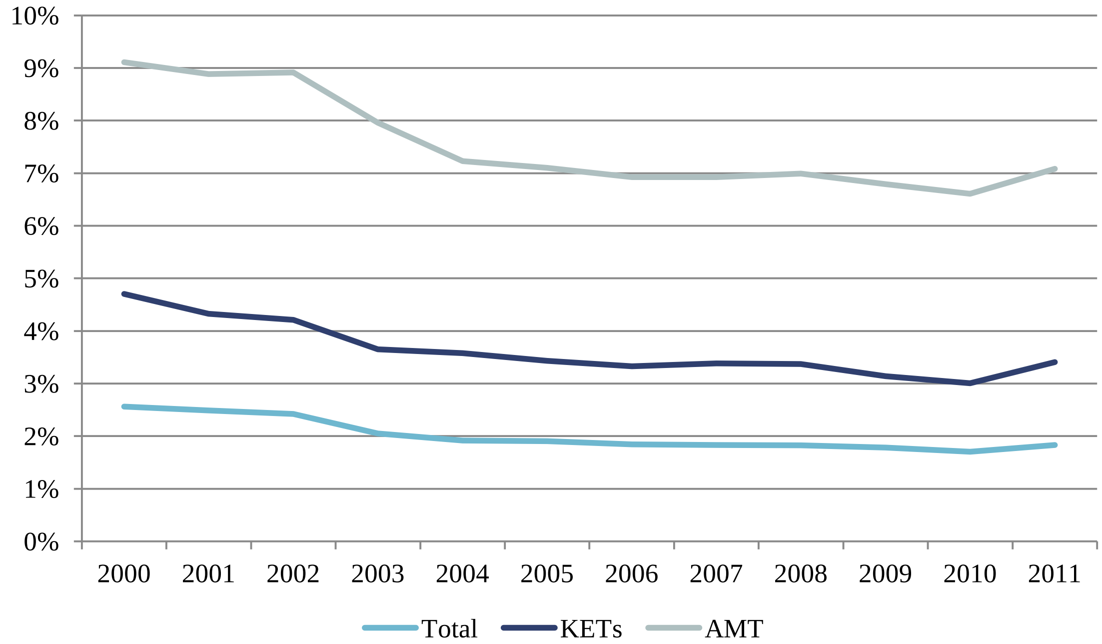
When looking at the share of patent applicants in total applicants at the transnational level (Figure 14), we see that the firms listed in the Scoreboard only constitute a very small share in total applicants. For the total number of applicants, the share lies at 2% in 2011, implying that these 2% are responsible for 58% of transnational filings. With regard to KETs filings the share is slightly higher (3%). In AMT, 7% of all applicants in AMT are covered. These 7% of firms are responsible for 57% of all transnational AMT filings in 2011.

Figure 13 Share of transnational patent filings covered by the matching



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Figure 14 Share of patent applicants covered by the matching



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

In sum, we find that 177 firms that are listed in the R&D Scoreboard do not file any patents, i.e. no link to a patent applicant in PATSTAT could be established. This might be due to several reasons:

- the firms are actually not patenting: among the firms where no patents were identified, there is a large share of investment companies, banks, consultancy firms and software and related service firms ("online games", "human capital and knowledge management software", "data providers").
- no subsidiary information for the firms was available: for 145 of the 181 firms with no patents, no subsidiary information was available. In case these firms file patents only via their subsidiaries, they cannot be identified with the data at hand.
- the algorithm is not able to find corresponding entries within the databases: as stated in section 5.2, an automated algorithm is generally not able to find all possible matches. Especially in the case of name changes of companies or usage of abbreviations, the string-matching algorithm cannot find corresponding entries. In these cases, manual checks were performed and company names were assigned manually.

Turning the analysis of the coverage the other way around, the patent applicants that are not covered by the matching can be analyzed. The top 10 of the largest patent applicants that are not covered by the matching, in total, for KETs and for AMT, are provided in Table 1. The majority of large non-covered applicants are universities and public research institutes, i.e. the *Commissariat a L'Energie Atomique (CEA)*, the *Centre National de la Recherche Scientifique (CNRS)* or the *Chinese Academy of Sciences (CAS)*. The remaining companies in the list are companies that are not covered by the R&D Scoreboard, as for example *Osram* or the *Yazaki Corporation*. Comparing the applicants listed in Table 2 with the top applicants in KETs and AMT (Table 1) it becomes obvious that all the major players within KETs and AMT, except for universities or public research institutes, are covered by the matching.

Table 4 Top 10 Applicants that are not covered by the matching, total, KETs and AMT, transnational filings, 2009-2011

Total	
Applicant name	**# filings**
CEA (COMMISSARIAT A L'ENERGIE ATOMIQUE)	1634
CNRS (CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE)	1491
SCHAEFFLER TECHNOLOGIES & COMPANY	1283
FRAUNHOFER	1144
PRAD RESEARCH AND DEVELOPMENT	1086
UNIVERSITY OF CALIFORNIA	1062
CHINESE ACADEMY OF SCIENCES	908
YAZAKI CORPORATION	881
HARVARD UNIVERSITY	846
OSRAM	714
KETs	
Applicant name	**# filings**
CEA (COMMISSARIAT A L'ENERGIE ATOMIQUE)	667
CHINESE ACADEMY OF SCIENCES	481
CNRS (CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE)	473
SEMICONDUCTOR ENERGY LABORATORY COMPANY	459
OSRAM	458
OSRAM OPTO SEMICONDUCTORS	452
FRAUNHOFER	347
UNIVERSITY OF CALIFORNIA	326
SHENZHEN CHINA STAR OPTOELECTRONICS TECHNOLOGY COMPANY	245
YAMAZAKI SHUNPEI	238
AMT	
Applicant name	**# filings**
CEA (COMMISSARIAT A L'ENERGIE ATOMIQUE)	110
FRAUNHOFER	76
SOCIETE NATIONALE D'ETUDE ET DE CONSTRUCTION DE MOTEURS D'AVIATION	71
CNRS (CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE)	61
SCHAEFFLER TECHNOLOGIES & COMPANY	56
MITUTOYO CORPORATION	48
SENJU METAL INDUSTRY COMPANY	40
PRAD RESEARCH AND DEVELOPMENT	40
HEIDENHAIN	38
AVL LIST	34

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

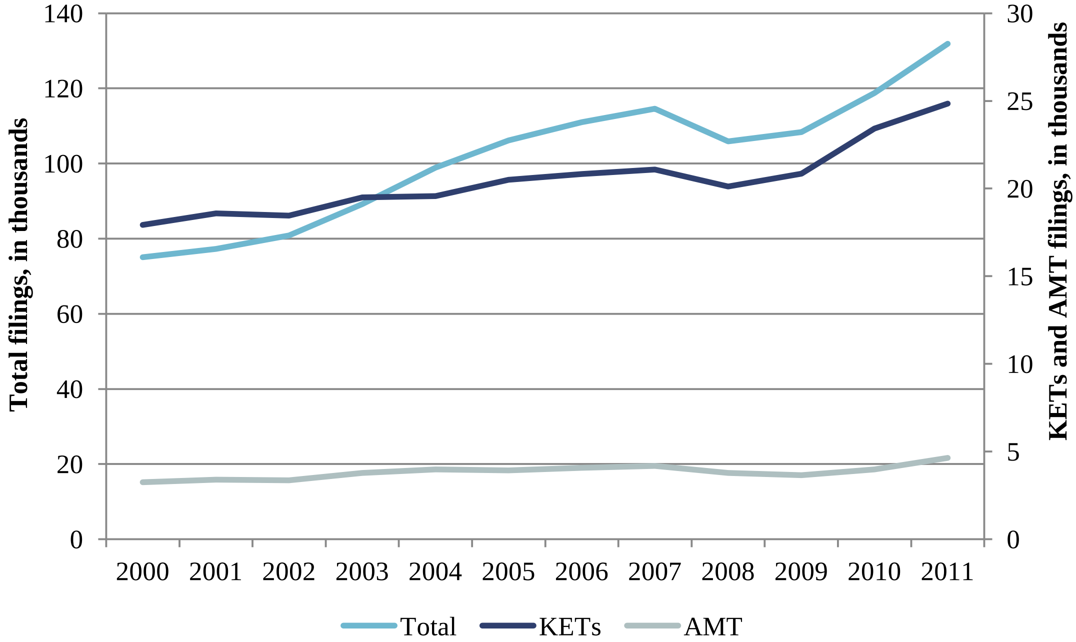
6 Patent trends within the R&D Scoreboard

In this section, the results of the matching will be presented, i.e. patenting trends for the firms in the R&D Scoreboard in total, for KETs and AMT at different aggregate levels are provided.

6.1 General trends

To getter a better idea on the amount of patents filed by the firms listed in the 2013 R&D Scoreboard and their patent activities in KETs and AMT, Figure 15 shows the number of transnational filings in total, for KETs and AMT over time. The total number of transnational filings by the firms listed in the Scoreboard resembles the general trends in patenting quite well.

Figure 15 Number of transnational filings by the firms in the R&D Scoreboard, total, KETs and AMT



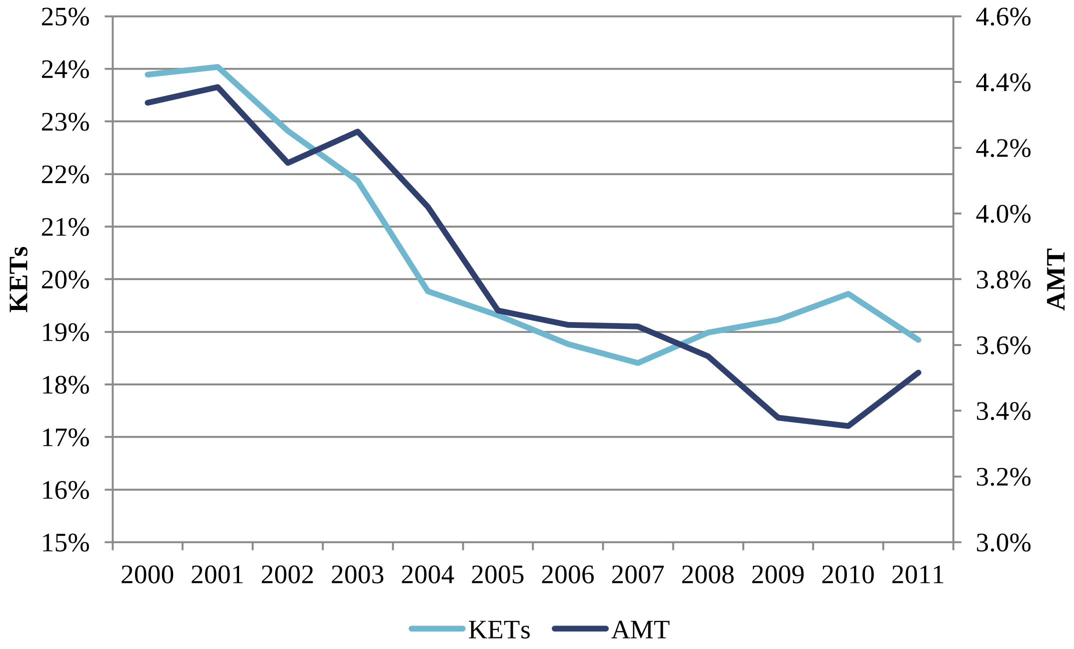
Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

The number of filings is rising between the year 2000 and 2007, followed by a decrease between 2008 and 2009, which is an effect that can be attributed to the economic crisis. In a sample of German firms, it has been found that this effect is not only due to a decrease in R&D expenditures during that time period but also can be attributed to cost-saving patent strategies of firms, e.g. filing less patents internationally etc. (Neuhäusler et al. 2014).

After 2008, however, the number of filings starts growing again, with a peak in 2011, where about 130,000 transnational filings of Scoreboard firms can be found. This constitutes a share of about 58% of all transnational filings in the given year (compare Figure 13). The trends in KETs and AMT patenting mostly follow the general trends, although at a lower level. In 2011, the firms in the R&D Scoreboard are responsible for about 25,000 transnational KETs filings and 4,600 AMT filings, which constitutes a share of 61% and 57% of total transnational filings within the two fields, respectively.

In Figure 16, the shares of KETs and AMT in total transnational filings of firms within the R&D Scoreboard are plotted. This graph corresponds to Figure 2, where the overall shares of KETs and AMT in total filings was provided.

Figure 16 Shares of KETs and AMT in total filings within the R&D Scoreboard, transnational



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

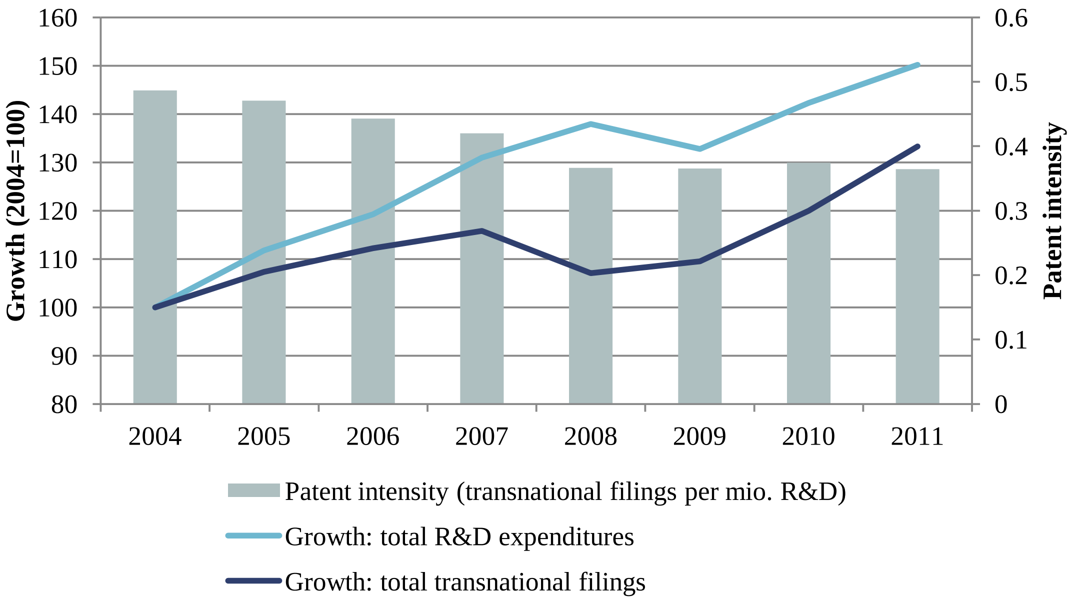
It can be observed that the trends within the R&D Scoreboard closely follow the overall trends. All in all, decreasing shares of KETs and AMT patents in total filings can be observed. Although the absolute numbers of patent filings in KETs and AMT have increased over the years, the growth in filings is below average. However, at least since 2007, the shares of KETs filings have been increasing. This can also be found for AMT since the year 2010.

With the combined PATSTAT/R&D Scoreboard dataset, we now also have the opportunity to relate the innovative outputs of the firms listed in the R&D Scoreboard to its inputs, i.e. we are able to calculate patent intensities (patent filings per million R&D expenditures) for the Scoreboard firms.

For the total number of transnational filings, this is shown graphically over time in Figure 17. On average, 0.36 patents per million R&D are filed in the year 2011. Besides the patent intensity, also the growth of R&D expenditures as well as transnational patent filings is plotted. It can clearly be seen that the patent intensity has decreased since

2004. It is lowest in 2008 and 2009 but slightly growing in 2010, which, at least partly, can be attributed to the financial crisis where the number of filings has decreased while the R&D expenditures have mostly remained at a constant level. Nevertheless, this is a surprising result, since the patent intensity has been constantly rising during the 1990s, i.e. the number of patent filings was growing fast, whereas the amount of R&D spent only rose moderately (see for example Blind et al. 2006). In the 2000s, the opposite seems to be true. At least for the firms in the R&D Scoreboard, the R&D expenditures are growing at a quicker pace than the patent filings, overall leading to a decrease in the patent intensity over the years. This means that in terms of R&D, generating patentable outcomes becomes more expensive or - vice versa - less patents can be filed per million R&D. This can be due to three reasons. First, companies file fewer patents, mainly fewer strategic patents. Second, complexity and R&D costs increase, so that generating results becomes a more expensive process. Third, an overall structural change occurs towards more R&D intensive or more expensive research fields.

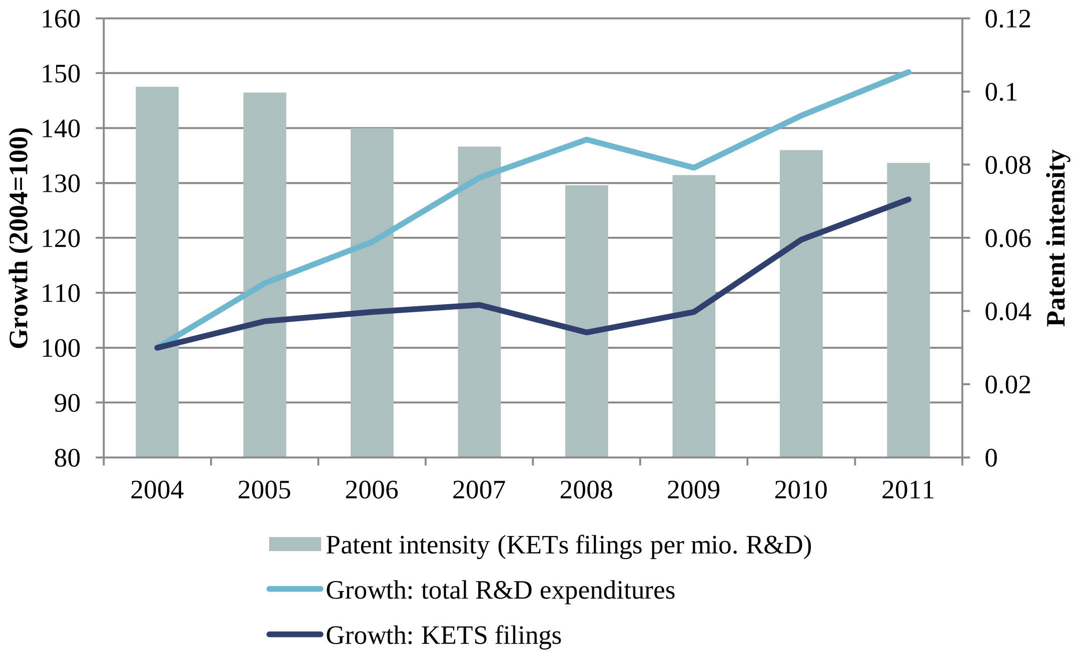
Figure 17 Patent intensities and growth of R&D expenditures and patent filings, total transnational filings, Scoreboard firms only



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only patenting firms with no missing information on R&D are taken into account.

Figure 18 and Figure 19 show the corresponding data for KETs and AMT filings, respectively. Since the R&D Scoreboard does not allow a differentiation of R&D expenditures by technology fields, the total amount of R&D expenditure of the firms in the sample has been used as a denominator in the calculations. This has to be kept in mind for the interpretation of the patent intensities, i.e. the patent intensity for the two fields are underestimated in total terms. However, it still allows for a comparison within KETs and AMT over time. As already discussed above, the growth in patent filings in KETs and AMT is below average, which leads to an even larger decrease in the patent intensity than it has been found in the case of total transnational filings. Yet, due to increasing shares of KETs and AMT filings in the recent years, the patent intensity has also been rising more strongly in these two fields.

Figure 18 Patent intensities and growth of R&D expenditures and patent filings, KETs filings, Scoreboard firms only



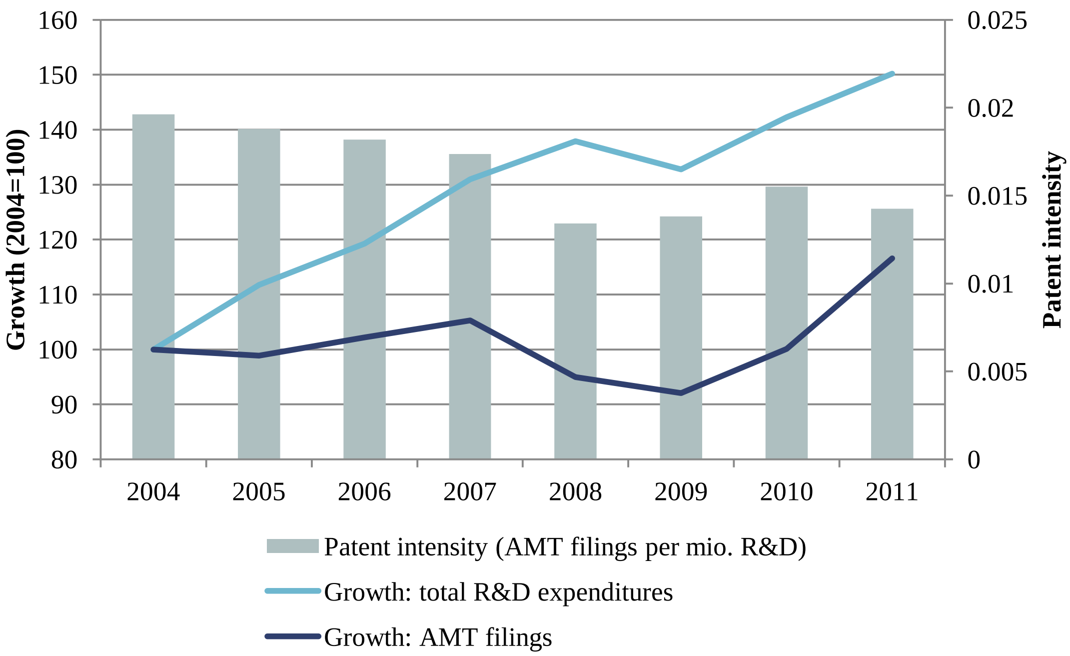
Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Note: Only patenting firms with no missing information on R&D are taken into account. Only the total R&D expenditures of a firm can be taken into account.

In Figure 17 to Figure 19, we have implicitly assumed that R&D has a direct influence on patenting, i.e. R&D in a given year is related to patenting in the same year. To test whether this assumption holds or we have to apply a time lag from R&D to patents, we have run several multivariate models on the interrelation between R&D and patents including several lags of the R&D variable of up to 5 years. For the models, the number of transnational filings was used as the dependent variable. The explanatory variables for the model are R&D expenditures with different time lags, i.e. in the same year, lagged by one year and so on. We repeat all models including the logged R&D expenditures variable to control for skewness in the distribution of the variable. To control for potential size effects, the number of employees were used as a control variable in the model. In addition, time dummies were included to account for period specific effects.

Three different model specifications were applied to test the interrelation between R&D and patent filings: an ordinary least squares (OLS) model, a negative-binomial model and a fixed-effects panel regression (XT(FE)). Since the number of patents is a count variable, an OLS model can lead to inefficient, inconsistent or biased estimates (Long 1997). The negative-binomial regression controls for these effects and is the more efficient estimator in this case. Since the data are in the form of company-level panel, we can also run a panel regression, which is best fitting our data structure.

Figure 19 Patent intensities and growth of R&D expenditures and patent filings, AMT filings, Scoreboard firms only



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Note: Only patenting firms with no missing information on R&D are taken into account. Only the total R&D expenditures of a firm can be taken into account.

After having estimated the models, the model fit (R^2) can be compared (Table 5) to find out in which time lag the R&D expenditures are best able to explain the variance in the number of transnational patent filings. Based on these values, we can see that, although there is a timely lagged effect of R&D on patent filings in all years, the relation between R&D expenditures and patent filings are highest in the model without time lag, i.e. in the same year. This is true across all three model specifications. It thus makes sense to plot the R&D expenditures to patent filings without time lag as in Figure 17 to Figure 19. We further conclude that a time-lag of t-0 will be used for further analyses.

Table 5 Model fit (R^2) of the different model specifications on the estimation of the relation between R&D expenditures and patents with time lag t-x

dV: Transnational filings	**OLS**	**Negative-binomial**	**XT (FE)**
R&D expenditures$_{t-0}$	0.477	0.077	0.025
R&D expenditures$_{t-1}$	0.469	0.075	0.013
R&D expenditures$_{t-2}$	0.459	0.075	0.014
R&D expenditures$_{t-3}$	0.450	0.074	0.013
R&D expenditures$_{t-4}$	0.445	0.072	0.018
R&D expenditures$_{t-5}$	0.441	0.072	0.061
Nr. of employees	YES	YES	YES
Time dummies	YES	YES	YES
Country dummies	YES	YES	YES
Industry dummies	YES	YES	YES
dV: Transnational filings	**OLS**	**Negative-binomial**	**XT (FE)**
Log R&D expenditures$_{t-0}$	0.313	0.103	0.009
Log R&D expenditures$_{t-1}$	0.308	0.101	0.008
Log R&D expenditures$_{t-2}$	0.301	0.100	0.008
Log R&D expenditures$_{t-3}$	0.292	0.099	0.010
Log R&D expenditures$_{t-4}$	0.283	0.099	0.015
Log R&D expenditures$_{t-5}$	0.276	0.099	0.027
Log Nr. of employees	YES	YES	YES
Time dummies	YES	YES	YES
Country dummies	YES	YES	YES
Industry dummies	YES	YES	YES

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

To find out what drives the patent intensity, two further OLS regression models with patent intensity as a dependent variable for the years 2006 and 2011 were calculated (Table 6). Besides including the amount of R&D expenditures and the number of transnational filings as control variables, we are interested in finding out whether the sizes of the firms, as measured by the number of employees, as well as their operating profits, influence the patent intensity. Furthermore, country group dummies as well as a service sector dummy are included to see which countries and sectors ceteris paribus have higher (lower) patent intensities.

Controlling for sector and country specific effects, we find a significantly negative coefficient for the firm size variable, indicating that larger firms have lower patent intensities than smaller ones. All else equal, operating profit, on the other hand, does not exert a significant influence on patent intensity. For the sector variable, it can be found that patent intensities are higher in industry than in the service sector, which is as expected. Among the country groups in comparison, it can be found that patent intensities are highest in European firms, followed by North America, Asia and the rest of the world.

Table 6 OLS model on patent intensity, 2006 and 2011

dV: Patent intensity	2006			2011		
	Coef.		S.E.	Coef.		S.E.
R&D expenditures (in millions)	-0.0002316	***	0.0000248	-0.0001532	***	0.0000160
Nr. of transnational filings	0.0011032	***	0.0000890	0.0007753	***	0.0000457
Nr. of employees	-0.0000007	***	0.0000003	-0.0000005	***	0.0000002
Operating profit (in millions)	-0.0000024		0.0000046	0.0000020		0.0000029
Service sector dummy (0=no, 1=yes)	-0.2024315	***	0.0318023	-0.1711856	***	0.0231554
Country group						
North America	-0.0758094	***	0.0289626	-0.0805616	***	0.0220315
Asia	-0.1183159	***	0.0300477	-0.0356241		0.0222252
Rest of the world	-0.1407688	***	0.0517116	-0.0836727	**	0.0359250
Constant	0.4723712	***	0.0239324	0.3527371	***	0.0174044
Nr. of obs.	1503			1738		
R^2	0.134			0.183		
F	28.89			48.31		
Prob > F	0.000			0.000		

Significance Level: ***p<0.01, **p<0.05, *p<0.1.

Note: Baseoutcome: Country group = Europe.

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

To get a more detailed overview on the country- and sector-specific effects, we re-ran the model replacing the country group variables by single countries (as dummy variables) and the service sector dummy variable by ICB sectors. The ICB sectors were manually aggregated to allow for variation within the sectors. These models are shown in Table 7. As for the country specific effects, we have seen in the above mentioned model that European firms have the largest patent intensities. In the more refined model, we can see that this is mostly due to the high patent intensities of Austria, Germany, Finland, France and the Netherlands. These countries have a significantly higher patent intensity than the USA, which serves as the base outcome for this model. The same is true for Japan. China and Taiwan, however, have significantly lower patent intensity than the USA, which drives the results for the group of the Asian countries.

Table 7 OLS model on patent intensity including detailed country and sectoral variables, 2006 and 2011

dV: Patent intensity	2006			2011		
	Coef.		**S.E.**	**Coef.**		**S.E.**
R&D expenditures (in millions)	-0.000200	***	0.000026	-0.000139	***	0.000016
Nr. of transnational filings	0.000936	***	0.000090	0.000678	***	0.000045
Nr. of employees	-0.000001	**	0.000000	0.000000	*	0.000000
Operating profit (in millions)	-0.000004		0.000005	0.000003		0.000003
Country						
AT	0.446	***	0.144	0.547	***	0.115
BR	--		--	-0.219	*	0.130
CN	-0.205	**	0.088	-0.177	***	0.041
DE	0.146	***	0.047	0.137	***	0.035
ES	-0.267	**	0.132	-0.070		0.087
FI	-0.040		0.099	0.185	**	0.080
FR	0.022		0.060	0.083	*	0.044
JP	0.000		0.032	0.133	***	0.025
KY	-0.207	**	0.091	-0.119	**	0.053
NL	0.340	***	0.100	0.026		0.060
TW	-0.220	***	0.055	-0.152	***	0.043
Sector (ICB aggregated)						
Oil, Gas & Alternative Energy	0.184	*	0.101	0.141	**	0.072
Chemicals	0.206	***	0.064	0.257	***	0.048
Mining, Metals, Forestry & Paper	0.045		0.088	0.095		0.061
Construction & Materials	0.025		0.085	0.045		0.062
Aerospace & Defence	-0.060		0.086	-0.018		0.066
Industrials, Ind. Engineering & Ind. Transp.	0.154	***	0.056	0.132	***	0.040
Electronic & Electrical Equipment	0.110	*	0.059	0.105	**	0.043
Support & Health Services, Media, Travel	-0.008		0.055	-0.023		0.041
Beverages, Food, Tobacco	-0.110		0.076	-0.107	*	0.056
Househ., Leisure & Pers. Goods, Home Const.	0.133	**	0.066	0.067		0.049
Pharmaceuticals & Biotechnology	-0.060		0.058	-0.076	*	0.043
Retailers	-0.204		0.146	-0.086		0.098
Telecommunications	0.080		0.116	-0.048		0.089
Electricity, Gas, Water & Multi-utilities	-0.198	**	0.097	-0.164	**	0.070
Financial Services	-0.241	**	0.114	-0.126	*	0.065
Technology Hardware & Equipment	-0.057		0.056	-0.003		0.041
Constant	0.352	***	0.051	0.224	***	0.038
Nr. of obs.	1503			1738		
R^2	0.204			0.286		
F	6.28			10.28		
Prob > F	0.000			0.000		

Significance Level: ***p<0.01, **p<0.05, *p<0.1.

Note: Baseoutcomes: Country = US, Sector = Automobiles & Parts. For countries only dummy variables with significant effects are shown.

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

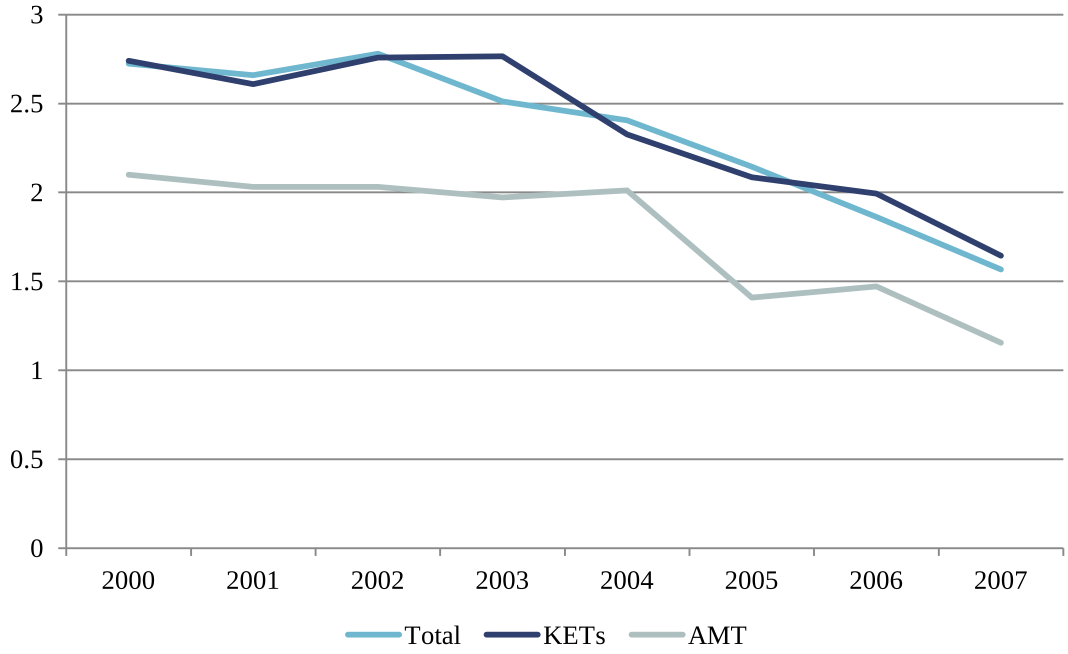
With regard to the sectoral effects it can be observed that firms in the sectors *Oil, Gas & Alternative Energy, Chemicals, Industrials and Electronic & Electrical Equipment,* show higher patent intensities on average than firms in the *Automobiles & Parts* sector, which is the base outcome for the industry dummy variables. Significantly lower intensities can be observed for *Beverages, Food & Tobacco Producers, Pharmaceuticals &*

Biotechnology, Electricity, Gas, Water & Multi-utilities and firms in the *Financial Services* sector.

Besides the mere output of patent filings, also an assessment of the value or quality of patent filings can be performed. This can be achieved via two indicators. First of all, the number of citations a patent receives from subsequent patent applications, commonly called patent forward citations, is analyzed. Patent forward citations probably are the most common and widely used indicator for the value of patent filings or patent portfolios of companies. Many scholars argue that forward citations, besides indicating technological spill-overs, are able to indicate the technological as well as economic value of a patent (Narin et al. 1987; Trajtenberg 1990). The basic assumption is that the number of forward citations measures the degree to which a patent contributes to further developing advanced technology, thus this can be seen as an indicator of technological significance (Albert et al. 1991; Blind et al. 2009; Carpenter et al. 1981). Here, the average number of forward citations in a four-year time window has been calculated and related to the number of patent filings per company in a given priority year. The time window assures that all patents have the same amount of time to be cited. Not using a time window would lead to higher citation counts for older patents, as they had a longer time period to be cited, which would cause a systematic bias.

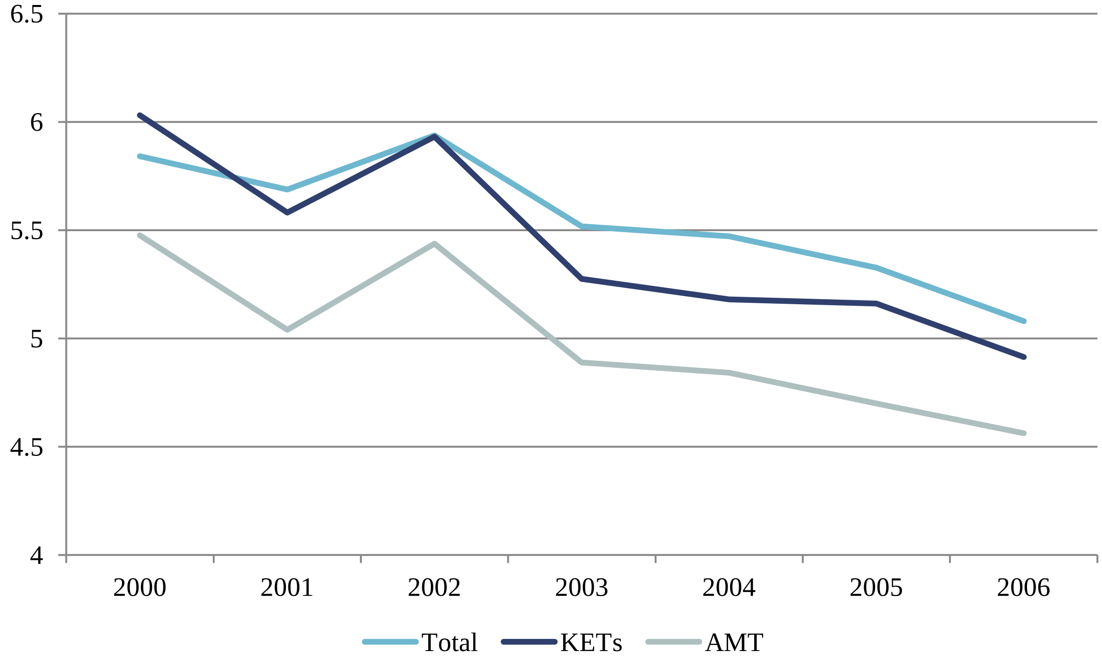
An additional indicator for the value of a technology portfolio is the (average) patent family size. It is determined by the number of countries or patent offices at which a patent has been filed (Martinez 2011; Putnam 1996; Schmoch et al. 1988) and thus first of all provides information about the internationalization of a company's patent portfolio. However, it also informs about the number of markets that are sought to be secured by the applicant to sell his invention. Since the costs for applying and upholding patents in foreign countries are high, it can be assumed that an applicant is only willing to bear those costs if he expects at least a corresponding profit. Thus, the size of the patent family can implicitly also be interpreted as an indicator of (economic) patent value.

Figure 20 Average number of forward citations, R&D Scoreboard firms only



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Figure 21 Average patent family size, R&D Scoreboard firms only



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

The average number of forward citations for the companies in the R&D Scoreboard is plotted in Figure 20. The average number of citations a patent receives from subsequent filings overall decreases over the years, leading to 1.5 citations per patent filing on average in the year 2007. In the most recent years, KETs patents are slightly more highly cited than average, with about 1.6 citations per filing. AMT filings on the other hand, are cited below average with only about 1.15 filings per patent.

With regard to the average patent family size (Figure 21), also a decreasing trend since the year 2000 can be observed. This is true for the total number of filings as well as for patent filings in KETs and AMT. This implies that patents in the more recent time periods are filed in fewer jurisdictions than in the early 2000s, i.e. patents are filed less broadly in terms of market coverage but concentrate on fewer patent offices. On average, about 5.1 patent offices are targeted per patent filing. This figure is somewhat lower for KETs filings with a value of 4.9. In AMT, the smallest average family size in comparison can be observed. The market coverage in terms of filings at different patent offices thus is more concentrated in AMT.

However, at an aggregate scale, especially these two indicators only provide a rather crude picture. Therefore, we have generated profiles of patent portfolios for the Top 10 patenting firms within the R&D Scoreboard (Table 8). With more than 3,500 filings in 2011, *Panasonic* is the largest transnational patent applicant in 2011, followed by the Chinese firms *Huawei* and *ZTE* with about 3,000 filings each. With regard to the patent intensity, i.e. patent filings per million R&D expenditures, we find comparable values across the firms. The two notable exceptions with rather high patent intensities are *ZTE* with 2.74 and Sharp with 1.55 patent filings per million R&D expenditures. Looking at the patents per employee, *Huawei*, *Sharp* and *ZTE* have the largest values. These three companies thus can be seen as having the largest patent output in relative terms. When looking at the patent value indicators, however, it can be found that filings from *ZTE* and *Huawei* are cited less frequently than the patents of their counterparts within this comparison. In addition, the average family size of these two companies is smallest, implying that *Huawei* and *ZTE* file patents less broadly in terms of patent offices covered. This shows that the evaluation of patent portfolios, especially at the firm level should be interpreted from quantity as well as from the quality side in order to get an impression of the "strength" of a company's patent portfolio. Finally, the table informs about applicant- and inventor locations of the companies, which provides hints about the internationalization of R&D activities of the companies. From the "applicant" point of view, we can observe from where the majority of patents of the companies have been filed, i.e. which share of patents are filed by applicants from the home country compared to patents filed by company parts or subsidiaries located in other parts of the world. From the "inventors" point of view, we gain information about where the inventors of a company are located, which at least gives us hints about the R&D locations of the respective firms.

Not surprisingly, the majority of applicant and inventor locations of the respective companies are in line with the location of the company headquarters. In the case of *Panasonic*, for example, 98% of applicants are located in Asia and only 1% is located in Europe and North America, respectively, implying that only few patents of *Panasonic* are filed by foreign company parts or subsidiaries. From the companies in this Top 10 list, *General Electric* shows the largest spread across countries in terms of applicants as well as inventors. Only 66% of the inventors from *General Electric* are located in North America. The remaining 34% are split up to Europe (20%) and Asia (14%). Since such large shares of inventors are located in foreign countries, it is reasonable to assume that *General Electric* also carries out R&D in those countries. The two other companies with a given spread of inventors (and applicants) across the world are the two German firms *Robert Bosch* and *Siemens*. In both cases, 83% of their patents are filed by inventors from Europe, but also inventor locations in North America, Asia and in the rest of the world can be found. Interestingly, all the Asian firms in the list have shares of "home-based" applicants as well as inventors that exceed 90%, indicating that the R&D and patenting activities are less internationalized.

Table 9 shows these company profiles for the Top 10 companies in terms of KETs patent filings. The largest number of transnational patents in KETs is filed by *Panasonic* with 904 filings in 2011, followed by *Sharp* (734 filings) and *LG* (558 filings). The largest share of KETs filings in total filings can be observed for *Applied Materials* where 86% of all company filings are within the field of KETs. The only other company in the Top 10 list where this share exceeds 50% is *LG*. For the remaining companies, shares between 13% and 37% can be observed. With regard to the patent intensity in KETs filings (KETs filings per million R&D expenditures of the firm in total), the highest value can be observed for *Sharp*. However, as stated above, we do not have information about the R&D spent specifically for KETs. The patent intensity for KETs thus just gives us a rough idea about the amount of KETs filings per million R&D and should be interpreted together with the share of KETs filings in total filings. The highest average number of forward citations can be found for *Sharp*, *Panasonic* and *Philips*. The two largest KETs applicants are thus able to also score high in terms of quality of the patent portfolio as measured by citations received from subsequent patents. *Philips*, however, has the largest average family size in comparison, i.e. the KETs patent portfolio of *Philips* is broadest in terms of covered markets.

Finally, Table 10 provides company profiles for the Top 10 companies in terms of AMT filings at the transnational level. *Siemens* is the largest technology providing company in AMT with 311 transnational filings in 2011. *General Electric* and *Robert Bosch* score second and third with 204 and 165 filings, respectively. The most highly cited AMT patent portfolios among the Top 10 AMT firms can be observed for *Panasonic*, *Toyota Motor* and *Yaskawa Electric* with *Toyota Motor* also having the largest average patent family size. The highest shares of AMT filings in total filings can be found for *Yaskawa Electric* with 53%, implying that *Yaskawa Electric* is relatively focused on AMT. This result is corroborated by the patent intensity in AMT (AMT filings per million R&D expenditures of the firm in total) of *Yaskawa Electric*, which is by far largest among the firms in comparison. With regard to the inventor locations, we once again find that *Siemens*, *General Electric* and *Robert Bosch* have comparably scattered R&D activities across the globe. Even more so, this can be found for *ABB*, where only 59% of inventors are located in Europe, 7% in North America, 11% in Asia and 24% in the rest of the world.

In sum, these company portfolios give us detailed information about the technology profiles of the firms as a whole as well as in KETs and AMT. The indicators in the matched PATSTAT/R&D Scoreboard dataset allow for a comparison of the companies listed in R&D Scoreboard with regard to quantity, quality and breadth of the patent portfolios.

Table 8 Profiles of the Top10 R&D Scoreboard companies by total patent filings, 2011

Company Name	PANA SONIC	HUAWEI	ZTE	SIEMENS	SAMSUNG ELECTRONICS	HITACHI	ROBERT BOSCH	TOYOTA MOTOR	SHARP	GENERAL ELECTRIC
Country	JP	CN	CN	DE	KR	JP	DE	JP	JP	US
R&D expenditures (in millions)	4556	2714	1110	4278	7235	3612	4242	6829	1356	3487
Employees	330767	80000	89786	402000	n.a.	323540	302519	325905	56756	301000
Transnational patent filings	**3529**	**3074**	**3038**	**2723**	**2280**	**2267**	**2232**	**2113**	**2107**	**2021**
Transnational filings per mio. R&D	**0.77**	**1.13**	**2.74**	**0.64**	**0.32**	**0.63**	**0.53**	**0.31**	**1.55**	**0.58**
Transnational filings per 1,000 employees	**10.67**	**38.43**	**33.84**	**6.77**	**n.a.**	**7.01**	**7.38**	**6.48**	**37.12**	**6.71**
Share of patents filed by inventors from Europe	2%	2%	0%	83%	4%	1%	83%	1%	2%	20%
Share of patents filed by inventors from North America	1%	5%	1%	11%	4%	1%	8%	1%	2%	66%
Share of patents filed by inventors from Asia	97%	92%	99%	4%	92%	98%	6%	99%	96%	14%
Share of patents filed by inventors from ROTW	0%	0%	0%	2%	0%	0%	3%	0%	0%	0%
Share of patents filed by applicants from Europe	1%	2%	0%	84%	2%	0%	84%	1%	1%	16%
Share of patents filed by applicants from North America	1%	5%	1%	10%	1%	1%	6%	1%	2%	80%
Share of patents filed by applicants from Asia	98%	93%	99%	5%	97%	99%	7%	99%	97%	5%
Share of patents filed by applicants from ROTW	0%	0%	0%	1%	0%	0%	3%	0%	0%	0%
Average family size (2006)	**4.25**	**3.31**	**2.64**	**4.18**	**4.23**	**4.11**	**4.11**	**5.15**	**4.06**	**4.52**
Average number of FW-citations (2006)	**3.52**	**1.29**	**0.54**	**1.19**	**1.23**	**2.35**	**1.25**	**3.02**	**3.59**	**1.59**
KETs filings (transnational)	904	66	31	479	216	447	301	189	734	374
AMT filings (transnational)	72	11	7	311	21	103	165	74	20	204

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Table 9 Profiles of the Top10 R&D Scoreboard companies by KETs filings, 2011

Company Name	PANA SONIC	SHARP	LG	FUJI FILM	SIEMENS	HITACHI	GENERAL ELECTRIC	PHILIPS	APPLIED MATERIALS	ROBERT BOSCH
Country	JP	JP	KR	JP	DE	JP	US	NL	US	DE
R&D expenditures (in millions)	4556	1356	n.a.	1518	4278	3612	3487	1768	847	4242
Employees	330767	56756	n.a.	81691	402000	323540	301000	125241	13000	302519
KETs filings (transnational)	**904**	**734**	**558**	**490**	**479**	**447**	**374**	**346**	**335**	**301**
KETs filings per mio. R&D	**0.20**	**0.54**	**n.a.**	**0.32**	**0.11**	**0.12**	**0.11**	**0.20**	**0.40**	**0.07**
KETs filings per 1,000 employees	**2.73**	**12.93**	**n.a.**	**6.00**	**1.19**	**1.38**	**1.24**	**2.76**	**25.77**	**1.00**
Share of KETs filings filed by inventors from Europe	0%	2%	0%	3%	83%	2%	13%	83%	12%	83%
Share of KETs filings filed by inventors from North America	1%	1%	0%	1%	11%	1%	72%	13%	86%	11%
Share of KETs filings filed by inventors from Asia	99%	98%	100%	96%	4%	97%	14%	4%	2%	4%
Share of KETs filings filed by inventors from ROTW	0%	0%	0%	0%	2%	0%	1%	0%	0%	2%
Share of KETs filings filed by applicants from Europe	0%	1%	0%	3%	87%	0%	12%	85%	10%	84%
Share of KETs filings filed by applicants from North America	1%	1%	0%	0%	10%	1%	83%	11%	88%	10%
Share of KETs filings filed by applicants from Asia	99%	98%	100%	97%	3%	98%	5%	3%	2%	4%
Share of KETs filings filed by applicants from ROTW	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Average family size (2006) (KETs filings only)	**4.24**	**3.98**	**4.99**	**4.37**	**4.06**	**4.46**	**4.54**	**6.00**	**4.94**	**4.04**
Average number of FW-citations (2006) (KETs filings only)	**3.50**	**4.01**	**2.77**	**2.95**	**1.21**	**3.28**	**1.56**	**3.34**	**0.91**	**1.17**
Transnational patent filings	3529	2107	1014	1309	2723	2267	2021	1491	390	2232
Share of KETs filings in transnational filings	26%	35%	55%	37%	18%	20%	19%	23%	86%	13%

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Table 10 Profiles of the Top10 R&D Scoreboard companies by AMT filings, 2011

Company Name	SIEMENS	GENERAL ELECTRIC	ROBERT BOSCH	MITSUBISHI ELECTRIC	HITACHI	ABB	YASKAWA ELECTRIC	TOYOTA MOTOR	PANA SONIC	HONEY WELL
Country	DE	US	DE	JP	JP	CH	JP	JP	JP	US
R&D expenditures (in millions)	4278	3487	4242	1366	3612	1095	91	6829	4556	1364
Employees	402000	301000	302519	117314	323540	133600	8246	325905	330767	132000
AMT filings (transnational)	**311**	**204**	**165**	**115**	**103**	**90**	**79**	**74**	**72**	**65**
AMT filings per mio. R&D	**0.07**	**0.06**	**0.04**	**0.08**	**0.03**	**0.08**	**0.87**	**0.01**	**0.02**	**0.05**
AMT filings per 1,000 employees	**0.77**	**0.68**	**0.55**	**0.98**	**0.32**	**0.67**	**9.58**	**0.23**	**0.22**	**0.49**
Share of AMT filings filed by inventors from Europe	81%	11%	78%	3%	2%	59%	0%	0%	0%	5%
Share of AMT filings filed by inventors from North America	12%	73%	16%	8%	4%	7%	0%	0%	3%	95%
Share of AMT filings filed by inventors from Asia	4%	14%	3%	89%	94%	11%	100%	99%	97%	0%
Share of AMT filings filed by inventors from ROTW	2%	1%	2%	0%	0%	24%	0%	1%	0%	0%
Share of AMT filings filed by applicants from Europe	86%	8%	81%	3%	2%	34%	0%	0%	0%	0%
Share of AMT filings filed by applicants from North America	12%	90%	14%	6%	3%	6%	0%	0%	3%	100%
Share of AMT filings filed by applicants from Asia	2%	2%	3%	91%	95%	5%	100%	99%	97%	0%
Share of AMT filings filed by applicants from ROTW	0%	0%	2%	0%	0%	55%	0%	1%	0%	0%
Average family size (2006) (AMT filings only)	**4.15**	**4.97**	**4.08**	**4.68**	**3.92**	**4.75**	**4.33**	**5.14**	**4.61**	**3.35**
Average number of FW-citations (2006) (AMT filings only)	**1.16**	**1.58**	**1.12**	**1.43**	**2.11**	**1.46**	**2.25**	**2.44**	**3.15**	**0.64**
Transnational patent filings	2723	2021	2232	1203	2267	750	149	2113	3529	543
Share of AMT filings in transnational filings	11%	10%	7%	10%	5%	12%	53%	4%	2%	12%

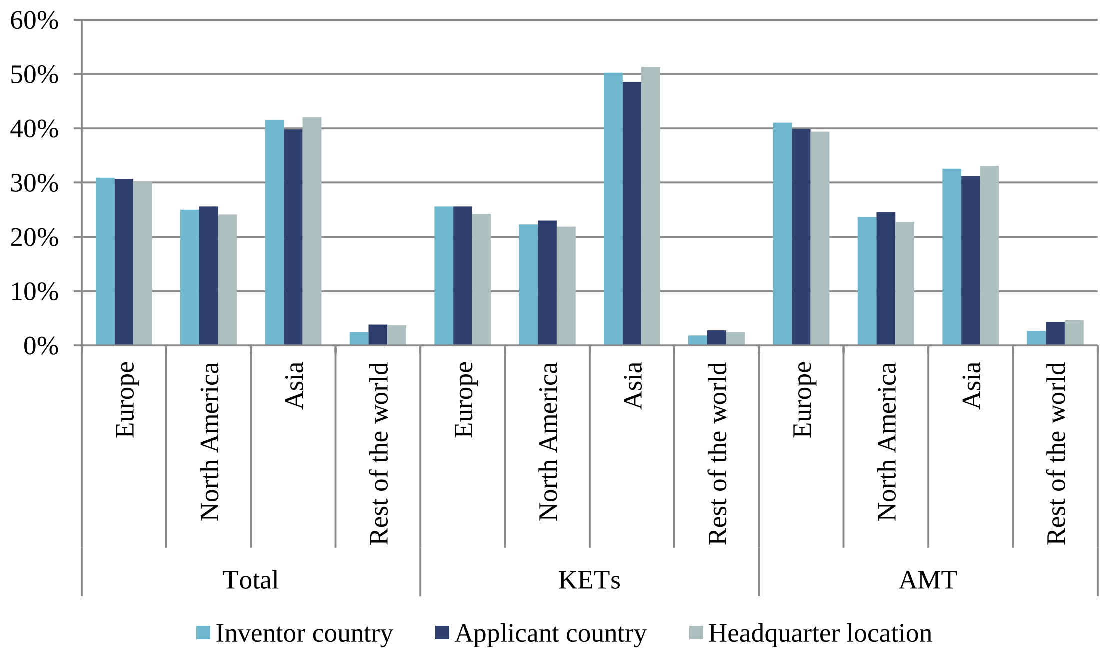
Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

6.2 Country-, sector-, and field-specific trends

In this section, country-, sector- and technology field-specific trends in patent filings of the firms listed in the R&D Scoreboard are provided. Besides filings in KETs and AMT, we also include the total number of filings which can be used as a reference frame to evaluate the indicators against the complete company set included in the Scoreboard.

In Figure 22, the country-specific trends in KETs and AMT filings by country-groups are presented. A differentiation by applicant and inventor countries as well as headquarter locations is shown. It can be observed, however, that at this level of aggregation the differentiation does not add very much to the discussion on applicant and inventor locations of the respective firms, i.e. the differences are rather small.

Figure 22 Country-group specific shares of transnational filings by different country definitions, R&D Scoreboard firms only, 2009-2011

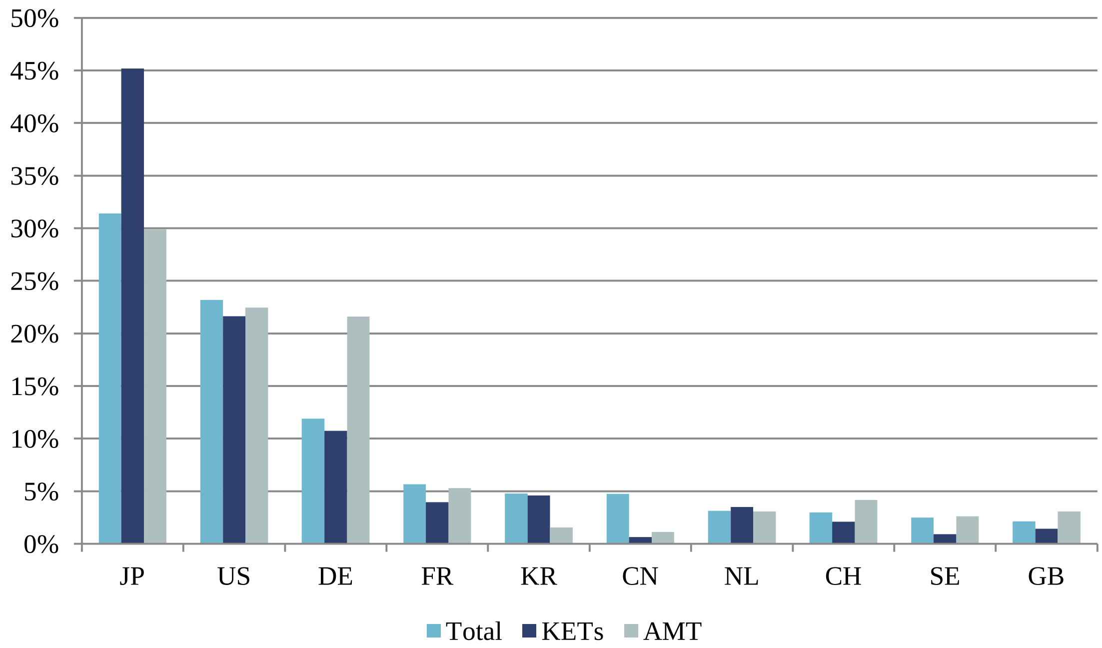


Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

The largest number of patent filings by Scoreboard firms stems from firms located in Asia, with a share of 40% in total filings. For firms located in Europe, this share lies at about 30%, followed by firms based in North America, which are responsible for about 25% of total filings by R&D Scoreboard firms. The remaining 5% originate from firms located in the rest of the world. This trend is similar, but even more strongly pronounced in the case of KETs. Asian firms are responsible for about 50% of all transnational KETs filings, followed by Europe (26%) and North America (22%). Firms located in the rest of the world are only responsible for 2% of KETs filings. Taken together with the results of total filings, it can be stated that KETs filings are more concentrated to Asian firms than total filings are. This counts at least for the large R&D performing firms listed in the R&D Scoreboard. In the case of AMT, however, the picture looks different. It can be observed that European firms are responsible for the largest share of AMT filings (about 40%), followed by firms from Asia (33%) and North America (24%).

In order to get more detailed information on these effects, Figure 23 shows the country specific trends by headquarter locations once again differentiated at the level of single countries. Here, we can see that the large amount of AMT filings in Europe mostly stems from German firms, which alone are responsible for 22% of AMT filings within the R&D Scoreboard.

Figure 23 Country specific shares in transnational filings by headquarter location, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

In Table 11, the leading innovators within economic sectors, i.e. Top3 of the largest Scoreboard firms within each economic sector is shown. For the sector differentiation the "Industry Classification Benchmark" (ICB) at the 3-digit level is applied.

Table 11 Top 3 patenting firms by economic sectors, ICB 3-digit, transnational filings, 2011

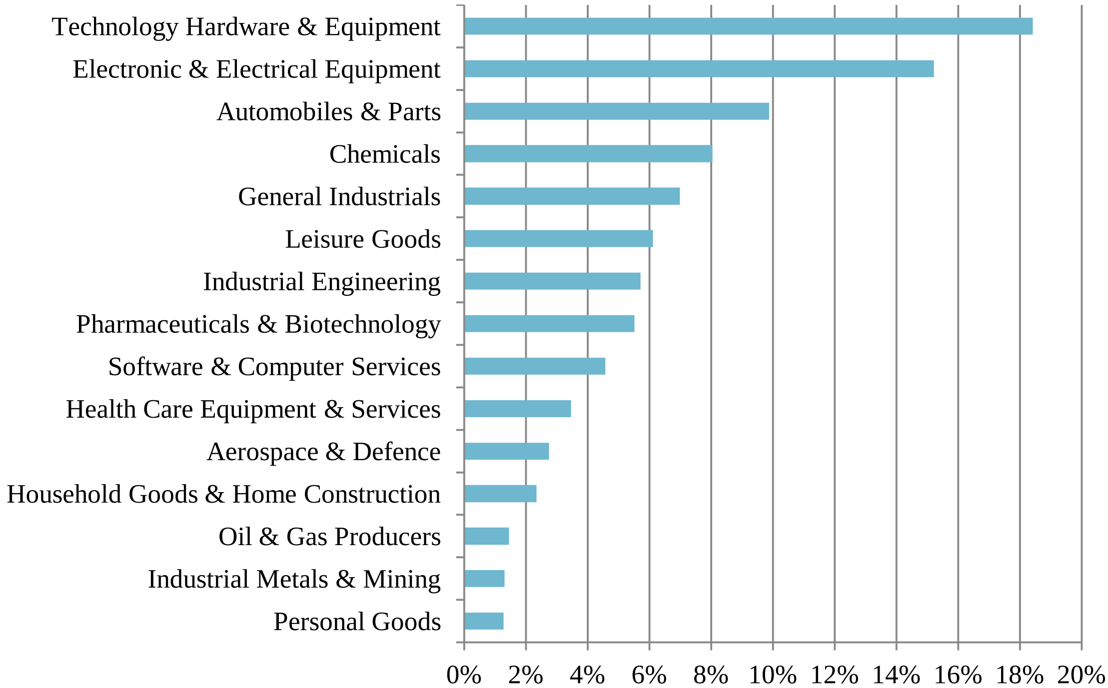
ICB code	ICB sector	Name	Nr. of transnational filings
530	Oil & Gas Producers	EXXON MOBIL	310
		ROYAL DUTCH SHELL	259
		JX	251
570	Oil Equipment, Services & Distribution	SCHLUMBERGER	476
		BAKER HUGHES	434
		HALLIBURTON	417
580	Alternative Energy	VESTAS WIND SYSTEMS	157
		SMA SOLAR TECHNOLOGY	31
		FIRST SOLAR	24
1350	Chemicals	BASF	962
		DOW CHEMICAL	673
		SUMITOMO CHEMICAL	558
1730	Forestry & Paper	SCA	71
		UPM-KYMMENE	53
		LINTEC	47
1750	Industrial Metals & Mining	NIPPON STEEL	394
		KOBE STEEL	243
		JFE	226
1770	Mining	ANGLO AMERICAN	56
		DOWA	41
		VALE	13
2350	Construction & Materials	SAINT-GOBAIN	305
		HILTI	136
		SEKISUI CHEMICAL	106
2710	Aerospace & Defence	UNITED TECHNOLOGIES	920
		EADS	671
		BOEING	412
2720	General Industrials	GENERAL ELECTRIC	2021
		PHILIPS	1491
		TOSHIBA	824
2730	Electronic & Electrical Equipment	SIEMENS	2723
		SAMSUNG ELECTRONICS	2280
		HITACHI	2267
2750	Industrial Engineering	ABB	750
		CATERPILLAR	407
		ALSTOM	398
2770	Industrial Transportation	DEUTSCHE POST	31
		AVICHINA INDUSTRY & TECHNOLOGY	4
		SNCF	2
2790	Support Services	GIESECKE & DEVRIENT	146
		TOPPAN PRINTING	77
		ACCENTURE	40
3350	Automobiles & Parts	ROBERT BOSCH	2232
		TOYOTA MOTOR	2113
		VOLKSWAGEN	721
3530	Beverages	MAXINGVEST	97
		PEPSICO	69
		KIRIN	38
3570	Food Producers	NESTLE	321
		UNILEVER	295
		MONDELEZ	83
3720	Household Goods & Home Construction	BSH BOSCH UND SIEMENS HAUSGERATE	619
		PROCTER & GAMBLE	610
		HENKEL	329
3740	Leisure Goods	PANASONIC	3529
		LG ELECTRONICS	1583
		SONY	1442
3760	Personal Goods	L'OREAL	313
		UNICHARM	219
		KAO	190
3780	Tobacco	JAPAN TOBACCO	105

		PHILIP MORRIS INTERNATIONAL	103
		BAT	92
4530	Health Care Equipment & Services	OLYMPUS	598
		COVIDIEN	356
		CARL ZEISS	296
4570	Pharmaceuticals & Biotechnology	JOHNSON & JOHNSON	569
		BAYER	563
		SANOFI-AVENTIS	519
5330	Food & Drug Retailers	AHOLD	1
		DELHAIZE	0
		WM MORRISON SUPERMARKETS	0
5370	General Retailers	AMAZON.COM	83
		EBAY	71
		TESCO	20
5550	Media	TECHNICOLOR	421
		DAI NIPPON PRINTING	113
		DOLBY LABORATORIES	103
5750	Travel & Leisure	NOVOMATIC	22
		SEGA SAMMY	12
		CENTRAL JAPAN RAILWAY	8
6530	Fixed Line Telecommunications	NTT	455
		FRANCE TELECOM	219
		DEUTSCHE TELEKOM	116
6570	Mobile Telecommunications	VODAFONE	60
		GOGO	2
		LG UPLUS	2
7530	Electricity	AREVA	87
		KOREA ELECTRIC POWER	47
		ELECTRICITE DE FRANCE	40
7570	Gas, Water & Multi-utilities	KURITA WATER INDUSTRIES	42
		VEOLIA ENVIRONNEMENT	37
		RWE	36
8350	Banks	UNICREDIT	66
		INTESA SANPAOLO	27
		BARCLAYS	11
8530	Nonlife Insurance	RSA INSURANCE	0
8570	Life Insurance	OLD MUTUAL	0
		STANDARD LIFE	0
8630	Real Estate Investment & Services	FINATIS	8
		IDB	1
8770	Financial Services	MASTERCARD	40
		ARQUES INDUSTRIES	17
		SBI HOLDINGS	8
8980	Equity Investment Instruments	HILL-ROM	37
8990	Nonequity Investment Instruments	SUNTORY HOLDINGS	31
9530	Software & Computer Services	NEC	1517
		FUJITSU	1019
		MICROSOFT	845
9570	Technology Hardware & Equipment	HUAWEI	3074
		ZTE	3038
		QUALCOMM	1826

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

To get an overview about the patenting activities across economic sectors, Figure 24 presents the sector-specific shares of patent filings for the Scoreboard firms at the ICB 3-digit level. In terms of total transnational filings, we find the largest share in the *Technology Hardware & Equipment* sector. About 18% of all filings by firms in the R&D Scoreboard are filed by companies located in this sector. The next largest sectors in terms of total transnational patent filings are *Electronic & Electrical Equipment* (15%), *Automobiles & Parts* (10%) and *Chemicals* (8%). In sum, this means that more than half of all filings by the Scoreboard firms stem from companies located in these four sectors. The other 50%, however, are relatively scattered across all sectors. A calculation of the Hirschman-Herfindahl Index (HHI), a measure of concentration, consequently shows a value of 0.09 on a scale from 0 to 1, with a value of 1 meaning a concentration of all filings in only one sector.

Figure 24 Shares of patent filings by sectors (ICB 3-digit), total transnational filings, R&D Scoreboard firms only, 2009-2011

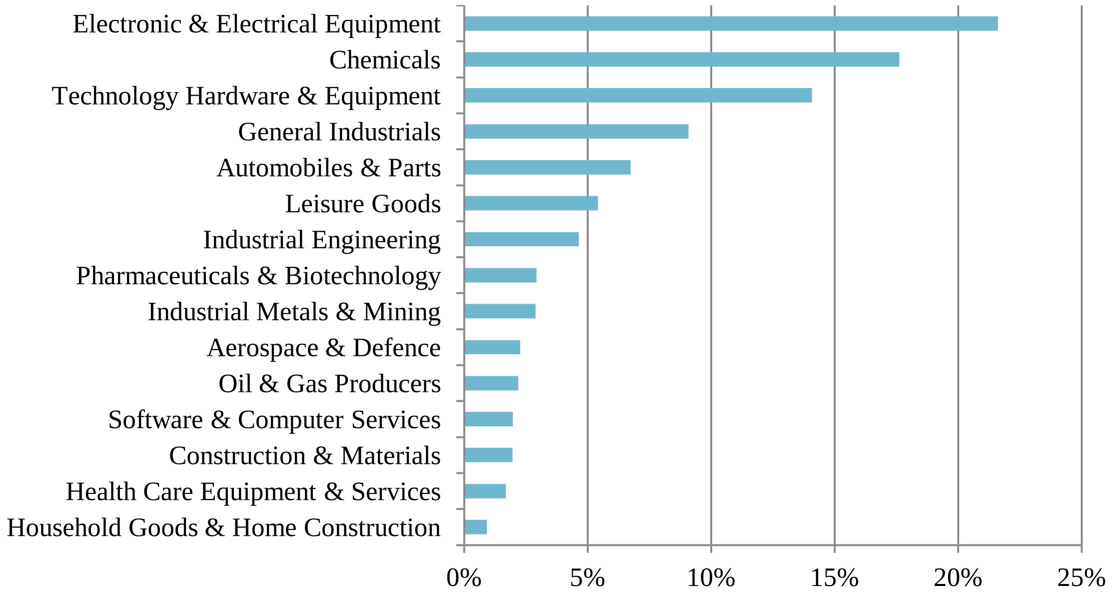


Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only the Top15 sectors with the largest shares of filings are shown.

In KETs (Figure 25), this picture looks only slightly different. Most of the KETs patents are filed by companies located in the sector Electronic & Electrical Equipment (22%), followed by Chemicals with a share of about 18%. About 14% of all KETs filings are filed by firms from the Technology Hardware & Equipment sector, 9% from General Industrials and 7% from firms located in the Automobiles & Parts sector. A HHI value of 0.12, however, shows that KETs filings also are rather spread across sectors. The same is true for AMT (Figure 26), where a HHI value of 0.13 can be observed. However, the sectors with the largest shares of AMT patents differ from the aforementioned. About 24% of all AMT patents are filed by companies from the Electronic & Electrical Equipment sector. About 16% come from the Industrial Engineering sector, followed by

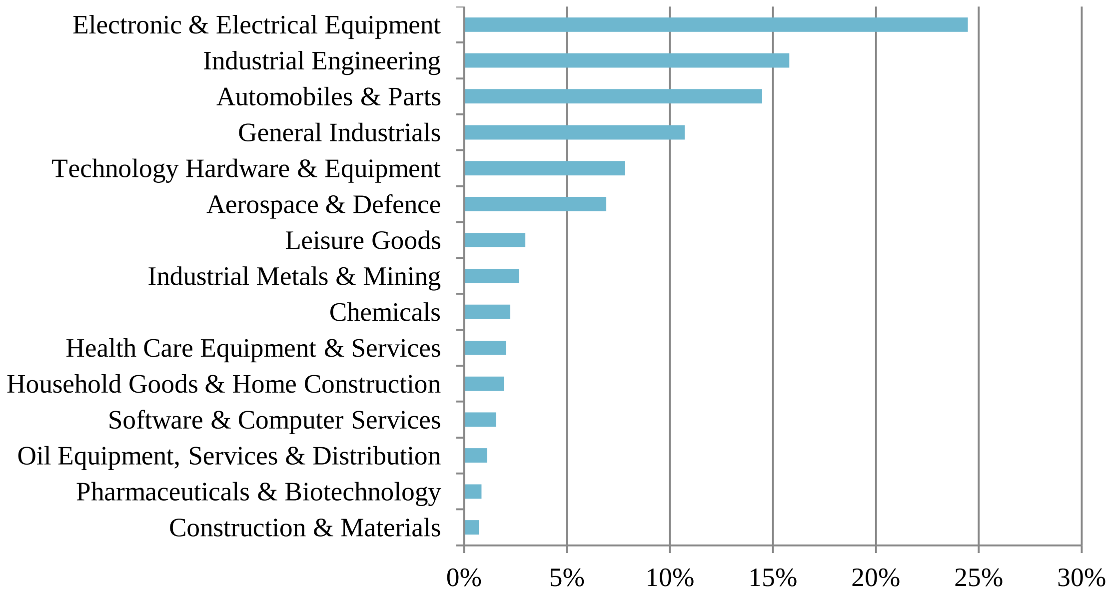
Automobiles & Parts (14%), General Industrials (11%), Technology Hardware & Equipment (8%) and Aerospace & Defence (7%).

Figure 25 Shares of patent filings by sectors (ICB 3-digit), KETs filings, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only the Top15 sectors with the largest shares of filings are shown.

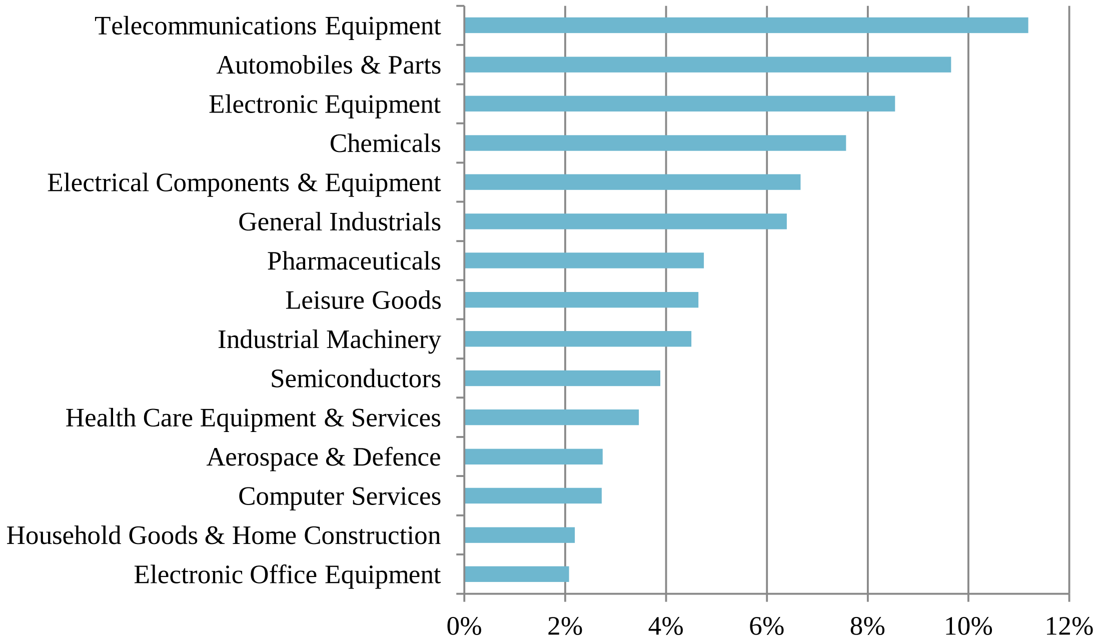
Figure 26 Shares of patent filings by sectors (ICB 3-digit), AMT filings, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only the Top15 sectors with the largest shares of filings are shown.

Differentiating the ICB at the 4-digit level shows that the subsector Telecommunications Equipment has the largest share on total patent filings with 11% (Figure 27). It is followed by the subsectors Automobiles & Parts (10%), Electronic Equipment (9%), Chemicals (8%) and Electrical Components & Equipment (7%).

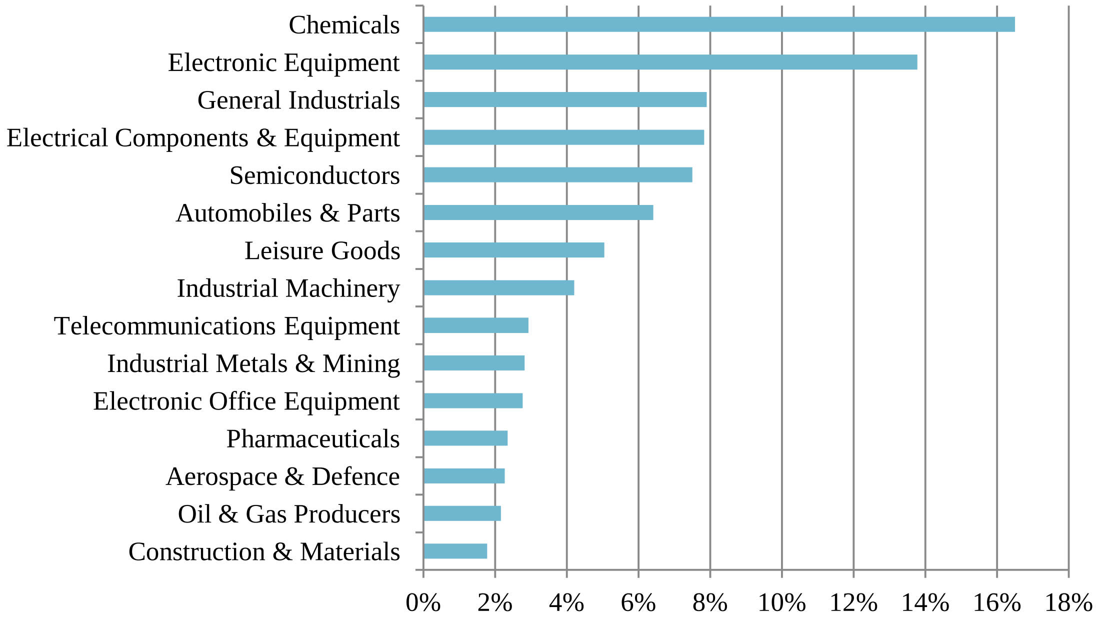
Figure 27 Shares of patent filings by sectors (ICB 4-digit), total transnational filings, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only the Top15 sectors with the largest shares of filings are shown.

Within KETs, the largest shares can be attributed to the subsectors Chemicals (16%), Electronic Equipment (14%), General Industrials (8%), Electrical Components & Equipment (8%) and Semiconductors (8%) (Figure 28). We thus observe a concentration of filings within Chemicals and Electronic Equipment. In AMT, the subsectors Automobiles & Parts (14%), Industrial Machinery (14%), Electrical Components & Equipment (14%), Electronic Equipment (11%) and General Industrials (10%) are responsible for more than 60% of all AMT filings (Figure 29).

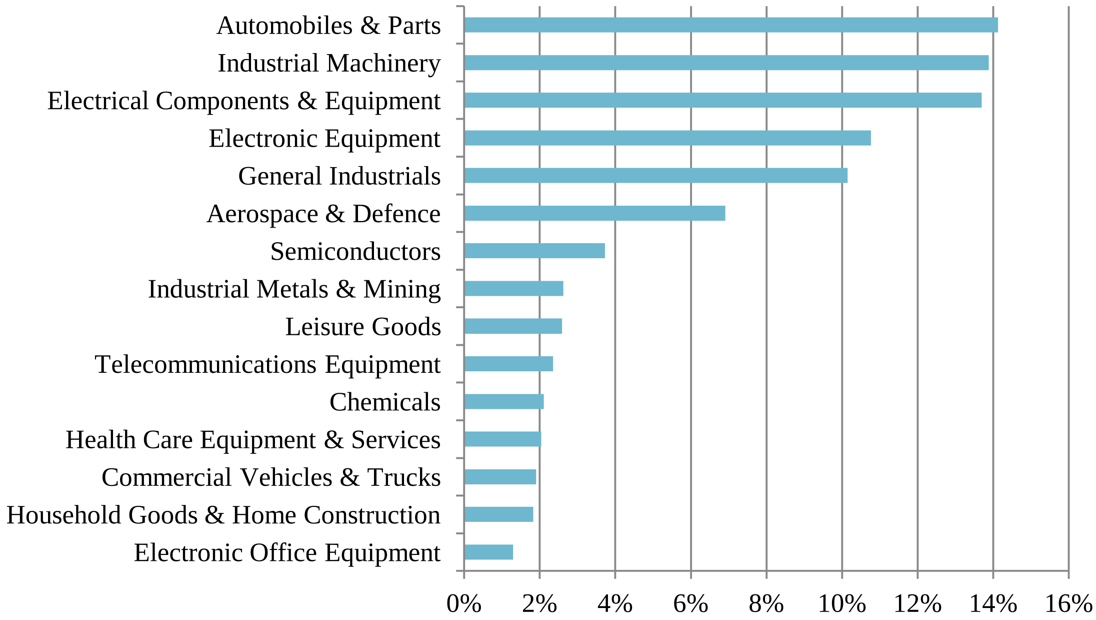
Figure 28 Shares of patent filings by sectors (ICB 4-digit), KETs filings, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Note: Only the Top15 sectors with the largest shares of filings are shown.

Figure 29 Shares of patent filings by sectors (ICB 4-digit), AMT filings, R&D Scoreboard firms only, 2009-2011

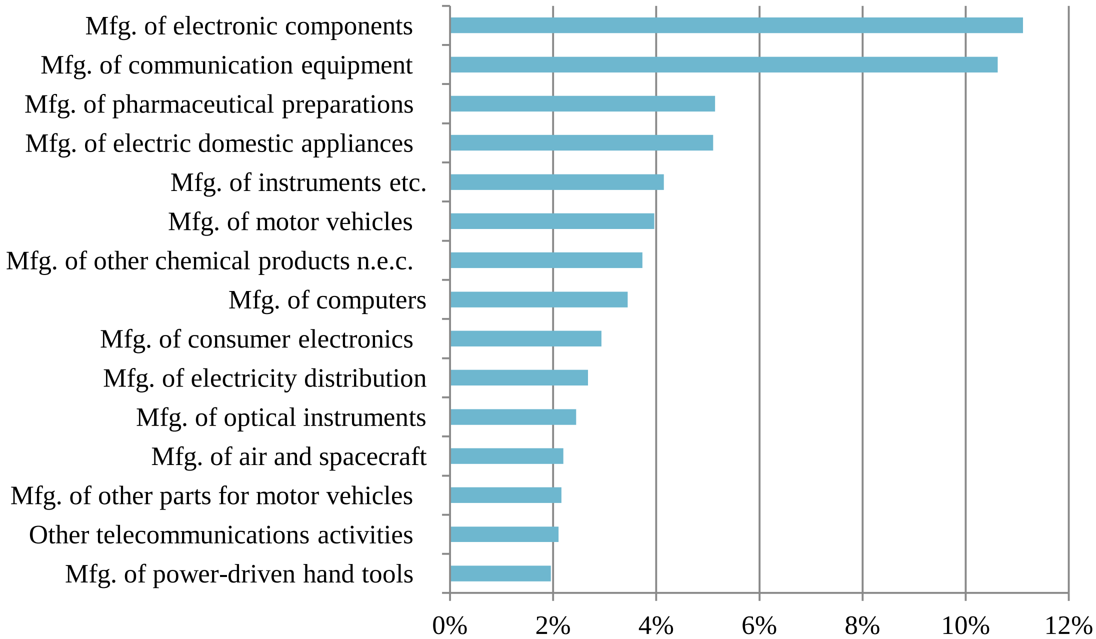


Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Note: Only the Top15 sectors with the largest shares of filings are shown.

Besides the sector differentiation of the ICB, the Scoreboard additionally allows for a differentiation of NACE (Rev. 2) sectors at the 4-digit level. The shares of patent filings are plotted by NACE sectors in Figure 30. The results of the differentiation by NACE sectors mostly are in line with the results for the ICB differentiation. The sector *Manufacturing of electronic components* is the largest within the Scoreboard in terms of total patent filings. About 11% of all filings from Scoreboard firms can be attributed to firms from this sector. It is closely followed by the sector *Manufacturing of communication equipment (10.6%).* With a share of about 5% each, the sectors *Manufacturing of pharmaceutical preparations* and *Manufacturing of electric domestic appliances* follow up these two sectors.

Figure 30 Shares of patent filings by sectors (NACE Rev. 2, 4-digit), total transnational filings, R&D Scoreboard firms only, 2009-2011

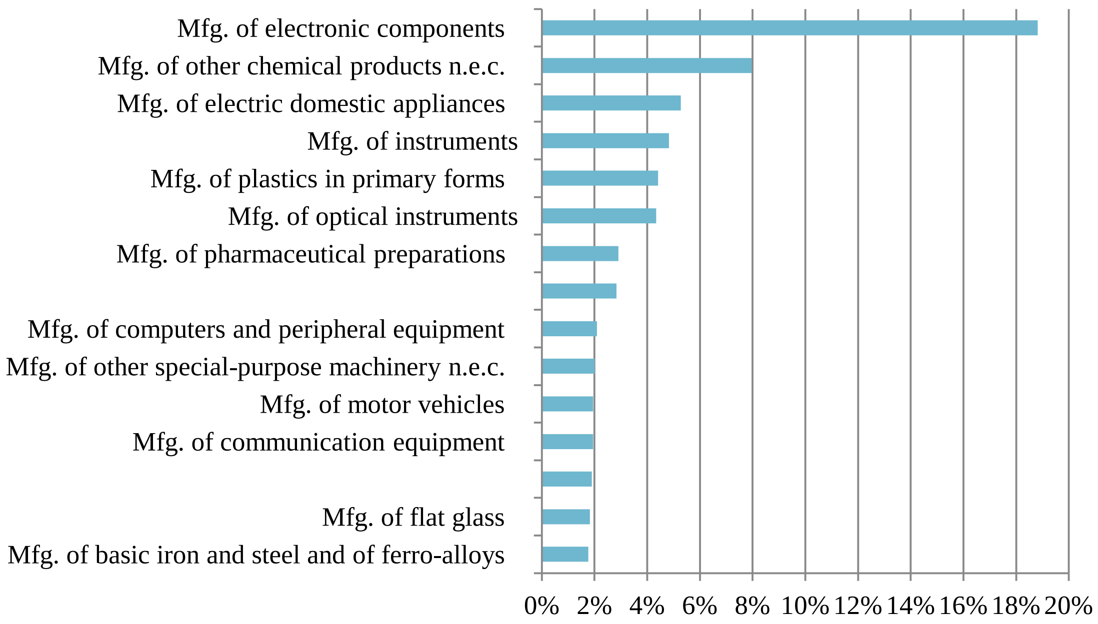


Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Note: Only the Top15 sectors with the largest shares of filings are shown.

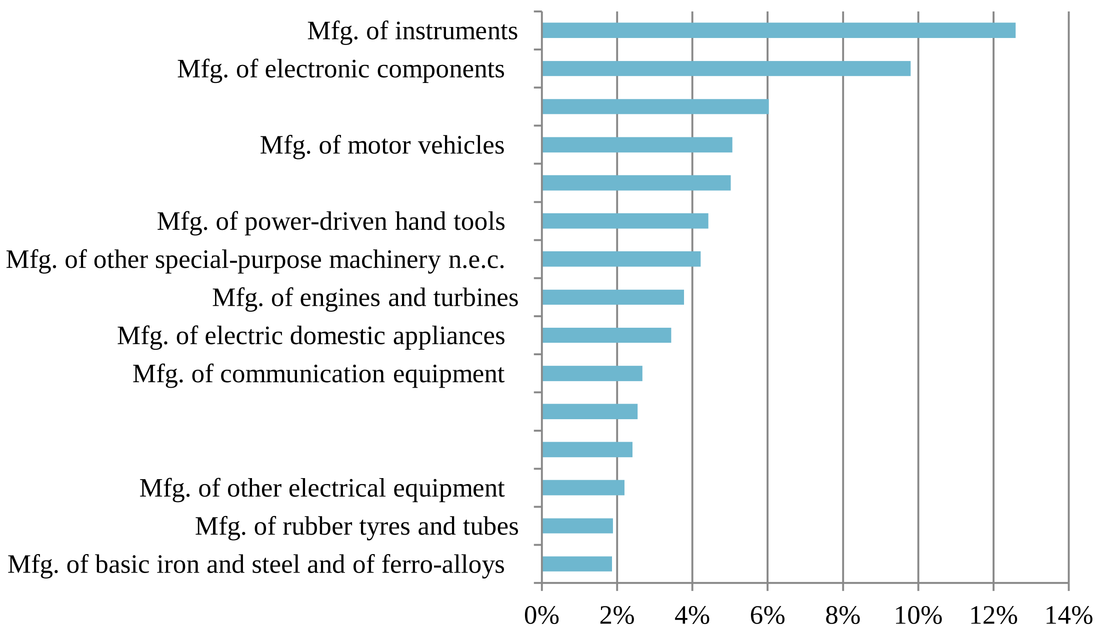
Within KETs (Figure 31), the firms located in the NACE sectors *Manufacturing of electronic components (19%)* and *Manufacturing of other chemical products n.e.c. (8%)* have the largest share of patent filings. This mirrors the results found in the ICB differentiation, although the shares there had been higher in *Chemicals* than in *Electronic Equipment*.

Figure 31 Shares of patent filings by sectors (NACE Rev. 2, 4-digit), KETs filings, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only the Top15 sectors with the largest shares of filings are shown.

Figure 32 Shares of patent filings by sectors (NACE Rev. 2, 4-digit), AMT filings, R&D Scoreboard firms only, 2009-2011

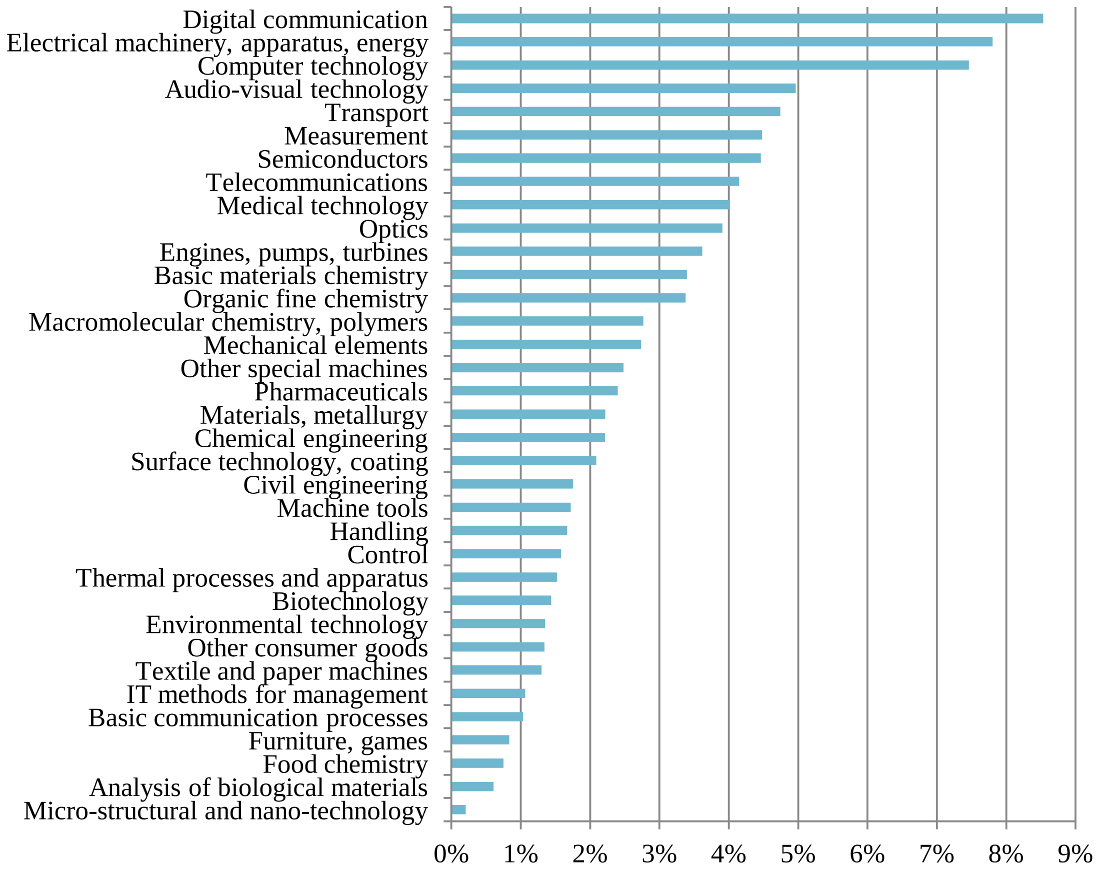


Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.
Note: Only the Top15 sectors with the largest shares of filings are shown.

Finally, Figure 32 provides the shares for AMT filings by NACE sectors. We find that the largest shares can be found in *Manufacturing of instruments (13%)*, followed by *Manufacturing of electronic components (10%), Manufacturing of air and spacecraft and related machinery (6%), Manufacturing of motor vehicles (5%)* and *Manufacturing of electricity distribution and control apparatus (5%)*.

In addition to the differentiation by sectors, the combined PATSTAT/R&D Scoreboard dataset also allows to differentiate the patent filings of Scoreboard firms by technology fields. This is plotted in Figure 33, based on the list of 35 WIPO fields (Schmoch 2008). The largest share of filings by R&D Scoreboard firms can be observed in the fields of *Digital communication*; *Electrical machinery, apparatus, energy*; *Computer technology* and *Audio-visual technology*. The smallest technology fields in terms of patenting are *Micro-structural and nano-technology*, *Analysis of biological materials* and *Food chemistry*.

Figure 33 Field-specific shares in transnational filings, WIPO35, R&D Scoreboard firms only, 2009-2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

6.3 Employment effects of R&D and KETs/AMT filings

In this section, we take a closer look at the employment effects of R&D expenditures and the relationship of KETs and AMT filings with employment. We therefore ran several regression models with the number of employees as well as employment growth as the dependent variables. Both variables are logged to account for the fact that there might be diminishing returns per additional employee.[8] In both types of models, we include R&D expenditures, the number of transnational patent filings and a dummy variable indicating whether a company has filed KETs patents (1=yes, 0=no) as explanatory variables. Additionally, the dependent variable with a one year time-lag is included in the models as a regressor to control for potential effects of endogeneity. Furthermore, time-, country- and industry dummy variables are added to control for period-, country- and sector specific effects.

Table 12 Multivariate models on the effects of R&D and KETs filings on employment

Model: XT(FE)	***dV: Log(nr. of employees)***			***dV: Log(employment growth)***		
	Coef.		**S.E.**	**Coef.**		**S.E.**
dV in t-1	0.52366	***	0.03187	-0.13314	***	0.01727
R&D expenditures (in millions)	0.00012	***	0.00002	-0.00011		0.00016
Nr. of transnational filings	0.00007	***	0.00002	0.00033		0.00032
Patent filings in KETS (dummy)	0.01102		0.00828	-0.05563		0.05805
Constant	4.25218	***	0.28059	-2.63452	***	0.07159
Time dummies		YES			YES	
Country dummies		YES			YES	
Industry dummies		YES			YES	
Nr. of obs.		11026			4631	
Nr. of groups		1838			1528	
R^2 (within)		0.4629			0.0622	
F		194.3			21.31	
Prob > F		0.000			0.000	

Significance Level: ***p<0.01, **p<0.05, *p<0.1.

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

8 In the case of the employment growth model, this implies that we have to interpret it in the form of a semi-elasticity, i.e. an absolute change in the regressor leads to a percentage change in the response variable.

In the second set of models, the KETs filings dummy is replaced by a dummy variable indicating whether a company has filed AMT patents (1=yes, 0=no) to specifically address AMT filings. All models are specified as fixed-effects panel regressions (XT(FE)).

Table 13 Multivariate models on the effects of R&D and AMT filings on employment

Model: XT(FE)	***dV: Log(nr. of employees)***			***dV: Log(employment growth)***		
	Coef.		**S.E.**	**Coef.**		**S.E.**
dV in t-1	0.52334	***	0.03187	-0.13311	***	0.01727
R&D expenditures (in millions)	0.00012	***	0.00002	-0.00011		0.00016
Nr. of transnational filings	0.00006	***	0.00002	0.00035		0.00032
Patent filings in AMT (dummy)	0.01811	**	0.00878	-0.07593		0.06901
Constant	4.25521	***	0.28093	-2.64155	***	0.06887
Time dummies	YES			YES		
Country dummies	YES			YES		
Industry dummies	YES			YES		
Nr. of obs.	11026			4631		
Nr. of groups	1838			1528		
R^2 (within)	0.4632			0.0623		
F	194.18			21.29		
Prob > F	0.000			0.000		

Significance Level: ***p<0.01, **p<0.05, *p<0.1.

Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

It can be observed from the models (Table 12 and Table 13) that R&D expenditures are significantly positively related to the number of employees. The same is true for the number of patent filings. With regard to KETs filings, no significant coefficient can be observed, while patent filings in AMT show a significantly positive coefficient. The number of employees, however, mostly captures a size effect. This means that there is a significantly positive correlation between firm size and AMT filings, while this cannot be confirmed for KETs in total.

When looking at the models capturing employment growth, no significant coefficients for the explanatory variables can be found in both models, i.e. it cannot be confirmed that R&D expenditures, patent filings or patent filings in KETs or AMT are directly positively related to the growth of a firm in terms of employment.

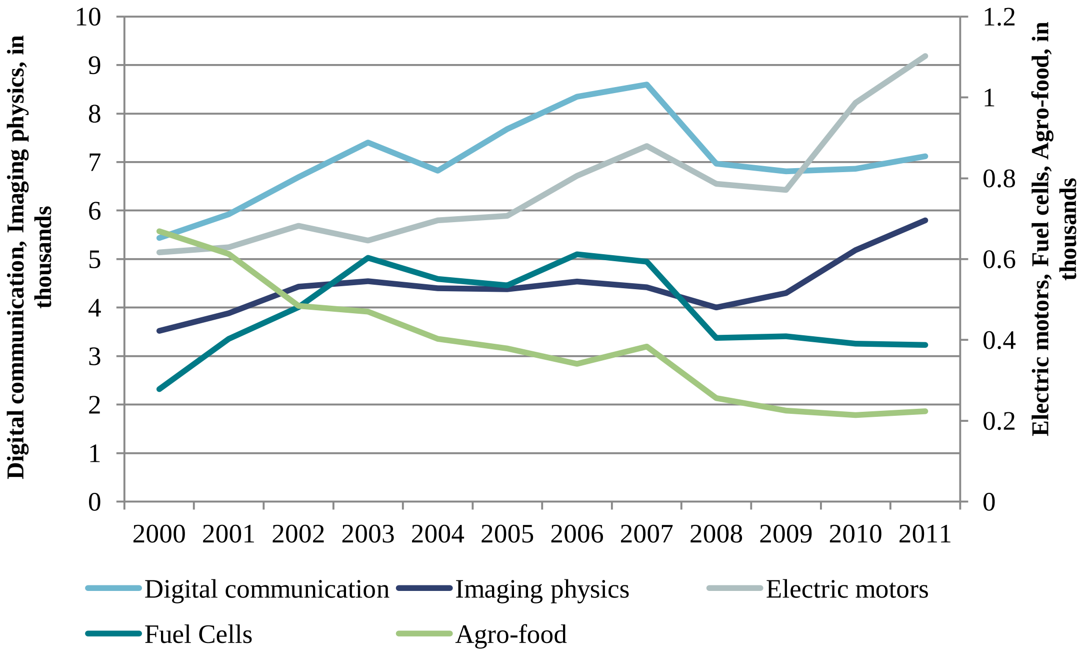
In sum, the interpretation of these models has to be done with care. There is a positive relationship between AMT filings and firm size, implying that AMT patents are more often filed by large firms. Larger firms are therefore more prone to patent filings within AMT than their smaller counterparts. With regard to employment growth, however, we find no significant effect of KETs or AMT filings.

6.4 Trends within specific technologies

Finally, we take a closer look at the patent trends within five exemplary technologies as examples of application oriented technologies that are related to KETs. The total number of transnational filings within these technologies by the R&D Scoreboard firms is depicted in Figure 34.

Among the technologies in comparison, *Digital information transmission* is the largest technology with slightly above 7,000 transnational filings in 2011. Second is *Imaging Physics*, a technology that has encountered a comparably large growth in transnational filings from 2008 onwards. In the year 2011, 5,800 filings by the firms listed in the R&D Scoreboard can be found. In the field of *Electric motors*, about 1,100 transnational patents have been filed in 2011. The two smallest fields within this comparison with filings below 1,000 in 2011 are *Fuel cells* and *Agro-food.*

Figure 34 Trends within specific technologies, total number of transnational filings, R&D Scoreboard firms only



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

In Table 14, the Top 10 companies with the largest number of transnational filings within the given technologies are presented. In *Digital information transmission,* Huawei files the largest number of transnational patents, followed by ZTE and Ericsson. In *Imaging physics,* the largest applicants are *Panasonic*, *Sony* and *Samsung Electronics*.

In *Electric Motors, Siemens, Mitsubishi Electric* and *Robert Bosch* can be found up front, whereas the largest companies in terms of transnational patent filings in *Fuel cells* are *Panasonic, Toyota Motor* and United Technologies. In *Agro-Food, BASF, DuPont* and *Dow Chemical* are the largest technology providing companies at the transnational level.

In a final step, the firms' filings within the respective fields were compared to the firms' filings in KETs and AMT, respectively. This is to find out whether patent filings in KETs and AMT are correlated to filings in more applications oriented fields.[9] For KETs, this is shown in Figure 35. The y-axis of the graphs shows the patent filings in KETs, while the x-axis provides the number of filings within the respective fields. The line denotes the polynomial trend line and indicates whether or not there is a correlation between KETs filings and filings within the respective fields. In sum, we find that there is a positive correlation between KETs filings and filings within the more application-oriented fields. This is especially the case for *Agro-food*, *Imaging physics* and to a lesser extent also for *Electric motors*. For *Fuel cells,* an inverted u-shaped relation can be observed, although the u-shape is mostly driven by only one company (else, the correlation would be negative). A negative correlation can be found for *Digital communication*, i.e. a larger amount of KETs filings is associated with a smaller number of filings within the field of *Digital communication*.

In AMT, the trends are a little bit different (Figure 36). Clearly positive relationships can be observed in the fields of *Electric motors* and *Agro-food*, implying that a larger number of AMT filings is positively associated to a larger number of filings within the two fields. Another u-shaped relationship can be found for *Imaging physics*, although once again the u-shape is largely driven by the filings from one firm. In *Fuel cells,* basically no correlation can be found, whereas it is negative in the field of *Digital communication.*

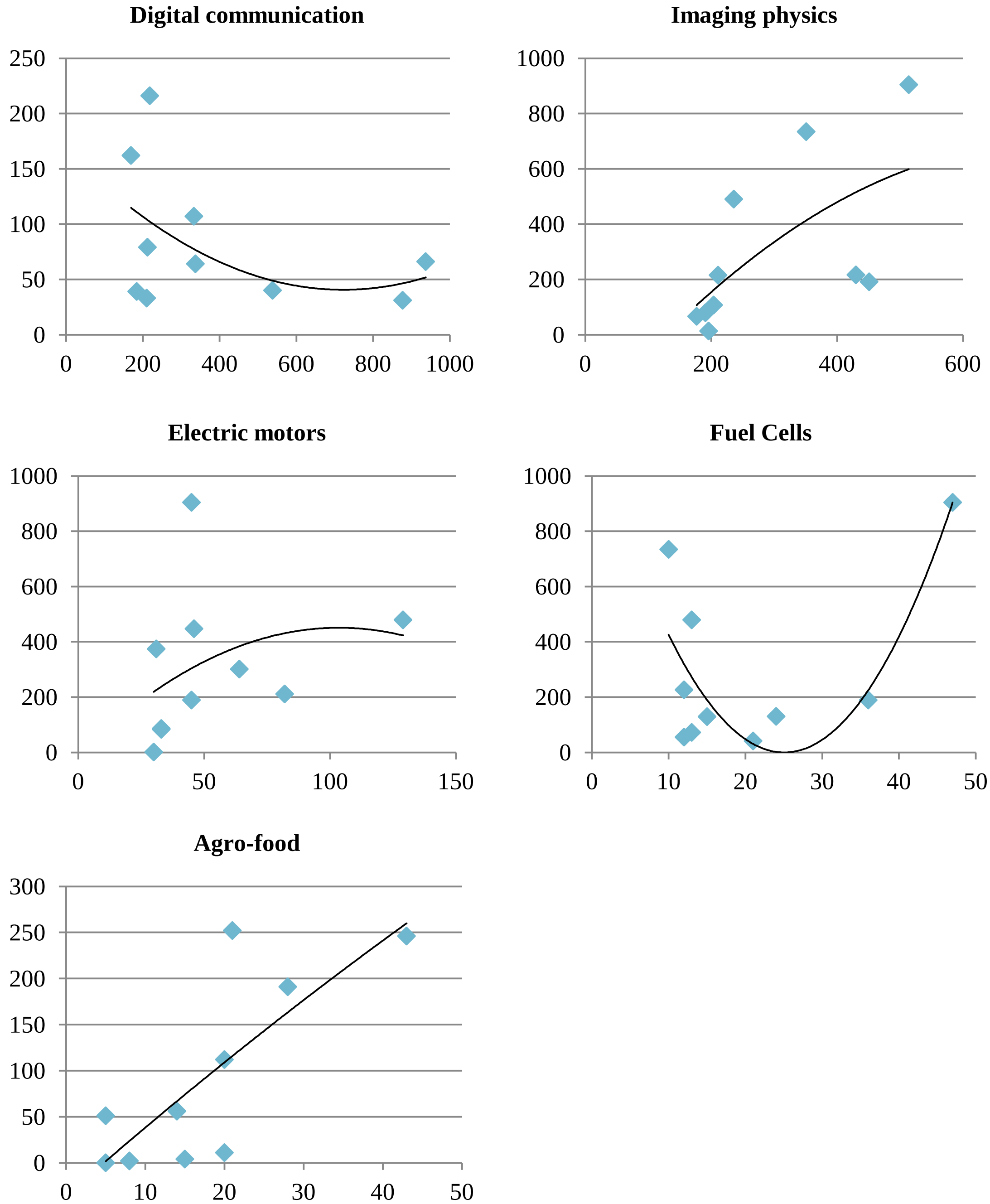
9 Once again, this might at least partly also reflect effects of cross-classification, i.e. filings that fall within the specific fields and are also assigned within the IPC-based definition of KETs and AMT.

Table 14 Top10 companies within the specific technologies, 2011

Country	Company name	# filings
	Digital communication	
CN	HUAWEI	937
CN	ZTE	877
SE	ERICSSON	538
FR	ALCATEL-LUCENT	337
US	QUALCOMM	333
KR	SAMSUNG ELECTRONICS	218
KR	LG ELECTRONICS	212
FI	NOKIA	210
CA	RESEARCH IN MOTION	184
JP	NEC	169
	Imaging physics	
JP	PANASONIC	514
JP	SONY	451
KR	SAMSUNG ELECTRONICS	430
JP	SHARP	351
JP	FUJIFILM	236
JP	CANON	211
US	QUALCOMM	204
FR	TECHNICOLOR	196
KR	LG ELECTRONICS	191
CN	HUAWEI	177
	Electric motors	
DE	SIEMENS	129
JP	MITSUBISHI ELECTRIC	82
DE	ROBERT BOSCH	64
JP	HITACHI	46
JP	PANASONIC	45
JP	TOYOTA MOTOR	45
FR	VALEO	33
JP	YASKAWA ELECTRIC	33
US	GENERAL ELECTRIC	31
DK	GRUNDFOS	30
	Fuel cells	
JP	PANASONIC	47
JP	TOYOTA MOTOR	36
US	UNITED TECHNOLOGIES	24
JP	NISSAN MOTOR	21
JP	JX	15
DE	SIEMENS	13
JP	SHOWA DENKO	13
JP	HONDA MOTOR	12
JP	MURATA MANUFACTURING	12
JP	SHARP	10
	Agro-food	
DE	BASF	43
US	DUPONT	28
US	DOW CHEMICAL	21
DE	BAYER	20
CH	SYNGENTA	20
US	MONSANTO	15
DK	NOVOZYMES	14
US	PHILIP MORRIS INTERNATIONAL	8
CH	ROCHE	5
US	REGENERON PHARMACEUTICALS	5

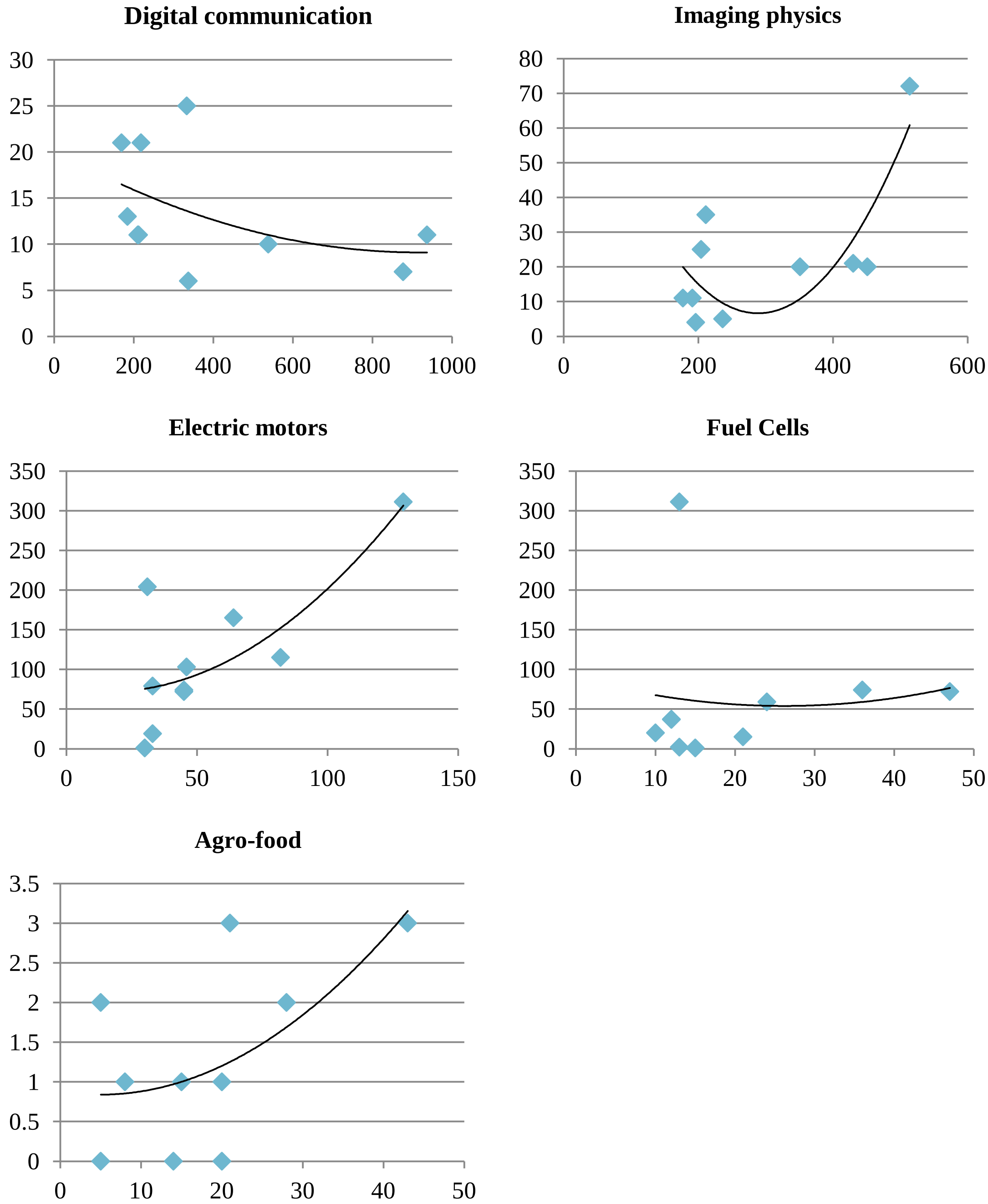
Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Figure 35 Top 10 firms' patent filings in KETs and the specific fields, 2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

Figure 36 Top 10 firms' patent filings in AMT and the specific fields, 2011



Source: EPO – PATSTAT, 2013 R&D Scoreboard, calculations by Fraunhofer ISI.

7 Conclusions and policy implications

In this study, empirical evidence on the role of innovation in Advanced Manufacturing Technologies (AMT) and Key Enabling Technologies (KETs) at the firm level was provided. The aim was to link input data – mainly R&D expenditures – with output indicators (patents) at the sectoral level, to be able to assess the European competitiveness of the largest R&D performers in selected technologies – namely AMT and KETs. In addition, the productivity in terms of patents per R&D in general as well as in the fields was under analysis. A precondition for the analysis was to match the data on R&D expenditures from the "EU Industrial R&D Investment Scoreboard" to patent data from the PATSTAT database. The patent indicators at the firm level allowed to assess and quantify the output of technology oriented R&D activities of the firms listed in the R&D Scoreboard in total terms and within KETs and AMT.

In 2011, about 41,000 transnational filings in KETs and 8,000 in AMT could be observed. AMT is the fourth largest subfield of KETs with a share of 18% of all KETs filings. Although the absolute numbers of patent filings in KETs and AMT have increased, the shares of KETs and AMT filings have decreased, implying that the number of KETs and AMT filings have grown below average in the last decade, although a larger growth has been found from 2007 onwards. This trend is also resembled in the analyses of the patent filings of the Scoreboard firms. The companies listed in the R&D Scoreboard are responsible for about 25,000 transnational KETs filings and 4,600 AMT filings in 2011, which adds to a share of 61% of all KETs and 57% of all AMT filings in that year. Since the firms listed in the Scoreboard only constitute a very small share in total applicants (2%), this once again provides evidence for the dominant position of large firms within the patenting scene, in general as well as in KETs and AMT. The Scoreboard companies, however, are the top R&D performers in the world, so they should also cover the largest share of patents.

Europe has highest shares in AMT with almost 50% of the patents. About 50% of these are originating from Germany headquartered companies in the Scoreboard, followed by France, the UK, Sweden and Italy. Japan is responsible for 27% and the USA for about 24% of all transnational AMT patents. In KETs it is Japan that clearly dominates the scene, followed by Europe and the USA. In this case, the technological contribution is more spread over Europe, with Germany again at the top, but more closely followed by France, the UK and the Netherlands. At this aggregate level, the choice of perspective, i.e. applicant vs. inventor vs. headquarter location, does not make a large difference.

The differentiation, especially by inventor countries, however, becomes important at the firm level as this gives hints on the R&D locations of certain firms.

The largest companies in terms of KETs filings are *Panasonic* with 904 filings in 2011, followed by *Sharp* (734 filings) and *LG* (558 filings). In AMT, the largest companies ranked by patent filings are *Siemens* (311 filings), *General Electric* (204 filings) and *Robert Bosch* (165 filings). Besides the absolute number of filings, however, also the patent intensity, defined as the number of filings per million R&D expenditures, was analyzed. On average, 0.36 patents per million R&D are filed in the year 2011. The time trends reveal that the patent intensity has decreased since 2004, on average as well as in KETs and AMT. This is an interesting result, showing that R&D expenditures were growing at a quicker pace than the patent filings in that time period. This is contrary to the trends of the 1990s, where patent filings were rising more quickly than R&D expenditures. Multivariate models on the patent intensity have shown that larger firms have lower patent intensities than smaller ones and that the patent intensity is higher in industry than in the service sector. Among the country groups in comparison, it can be found that patent intensities are highest in European firms, followed by North America, Asia and the rest of the world.

The value of KETs and AMT patents and their breadth in terms of market coverage compared to the total number of patent filings has been assessed via the number of citations they have received from subsequent filings as well as the average patent family size, i.e. the number of distinct offices the average KETs and AMT patents have been filed. It could be found that KETs patents are slightly higher cited than the average patent in the recent years, whereas AMT patents are cited below average. With regard to the market coverage, it could be observed that about 5.1 patent offices are targeted per patent filing. This figure is somewhat lower for KETs filings with a value of 4.9. In AMT, the average family size is 4.6. The market coverage in terms of filings at different patent offices thus is more concentrated in AMT.

The matched R&D Scoreboard/PATSTAT dataset additionally allows for a differentiation of KETs and AMT filings by economic sectors. Within KETs, the largest shares of filings can be found in *Electronic & Electrical Equipment and Chemicals.* Firms in the *Electronic & Electrical Equipment* sector also are responsible for the largest shares of filings in AMT. Large shares, however, can also be found in the *Industrial Engineering* sector followed by *Automobiles & Parts and General Industrials.*

With regard to the employment effects of R&D, it can further be found that R&D expenditures and patent filings are significantly positively related to the number of employees. A positive correlation with the number of employees can, ceteris paribus, also be found for firms who have filed AMT patents. This implies that larger firms are more prone to patent filings within AMT. With regard to employment growth, however, we find no significant effect of KETs or AMT filings.

Finally, the study has provided analyses of patent filings of firms listed in the R&D Scoreboard in specific technology fields that are related to KETs and AMT. Among the technologies in comparison, *Digital information transmission* is the largest technology with slightly more than 7,000 transnational filings in 2011, followed by *Imaging Physics* and *Electric motors*. The two smallest technologies within this comparison are *Fuel cells* and *Agro-food* with filings numbers below 1,000 in 2011.

The findings allow at least two different conclusions, relating to policy implications for the European Commission as well as the member states. First of all, Key Enabling Technologies are a heterogeneous group of fields. What we can derive from the analyses is that across all sub-fields of KETs they deserve their title. They are enablers for innovation and technological progress in many other sectors and fields, but at least for Europe they are not a sufficient, but just a necessary precondition for innovation success. In addition, direct growth and especially employment effects as they are intended by the Innovation Union Strategy are not to be expected in a short- to mid-term perspective. It rather seems to be the case that mastering KETs supports keeping the current competitiveness. One explanation is that other countries – among them at the top: Japan – also heavily invest in KETs and are able to rely on long-lasting experiences and specialization advantages emerging out of economies of scale and of scope, so that catching-up or even keeping track is an enormous effort. Another explanation is that some of the KETs, for example nanotechnology or micro- and nano-electronics as well as parts of advanced materials do not yet have fully developed their market potential, which might just start in the present and near future. The fact that Europe was not really able to catch up in terms of technological capabilities in the past years is even more disillusioning against this background. The economic successes might – on the average of all KETs – occur in other regions in the world – mainly in Japan and maybe in China. However, in some of the KETs that are about to enfold their market potential, the relative position of Europe is not too bad. In electronics and biotechnology it might be hard to move to the top of the technological development. For policy makers in Europe this has two important implications. On the one hand, the efforts to keep track should not be reduced. On the other hand, and this is even more important, a selective and existing capability augmenting strategy might be more appropriate than the expectation of a general technological leading position in all KETs. Furthermore, given the internationalization of research and innovation as well as a general opening of the innovation processes in companies, a strategy in finding a suitable position in global value- and innovation chains is also a reasonable task for the near future.

AMT is such a strength that could be extended. The considerable concentration of AMT capabilities in Germany and a few other large countries in Europe is a chance as this exactly offers the economies of scale and scope, which are not yet present in KETs. A broadening of the basis as well as network effects within Europe might be worthwhile to strive for.

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