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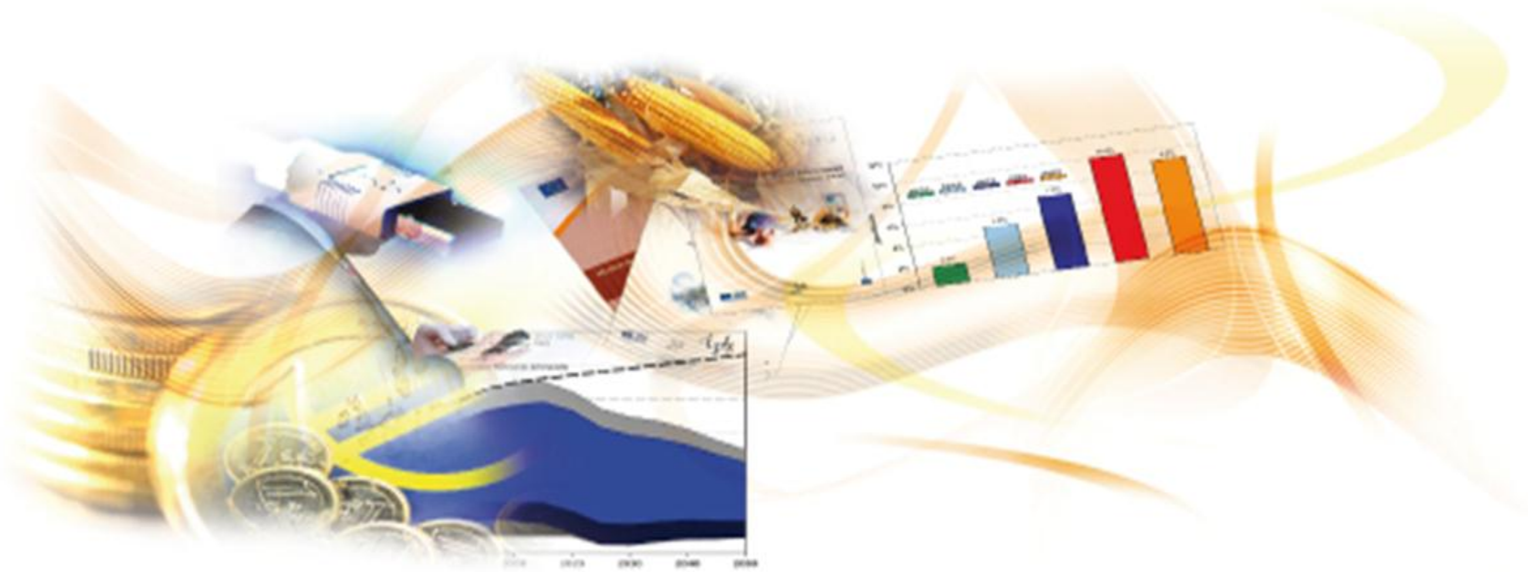

The capability of the EU R&D Scoreboard companies to develop Advanced Manufacturing Technologies

An assessment based on patent analysis

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Abstract
In this report the first results obtained from data provided by Fraunhofer Institute for Systems and Innovation Research (ISI) in the context of the Advanced Manufacturing for Competitiveness project are presented. The aims of this project are to develop and test a methodology based on patent analysis to assess the capacity of the EU Industrial R&D Scoreboard companies to develop advanced manufacturing technologies (AMTs) and key enabling technologies (KETs) which are expected to have a major impact on productivity, efficiency, profitability and employment in the major industrial sectors. The companies listed in the EU Industrial R&D Scoreboard hold a dominant position in KET and AMT filings accounting for about 61 % of total KET filings and 57 % of total AMT filings in 2011. European companies hold almost 50 % of the AMT worldwide patent filings and about 50 % of these are held by Germany headquartered companies. Japanese companies are responsible for 27 % of AMT filings worldwide and US companies for about 24 % of all transnational AMT patents. In KETs Japanese companies dominate the scene, followed by Europe and the USA. Developing and patenting AMTs and KETs seems to have become more expensive over the time period under study, as shown by the decrease in the average patent intensity since 2004. Although R&D expenditures and numbers of patent filings are significantly positively correlated with the number of employees, larger firms have lower patent intensities than smaller ones. In addition the patent intensity is higher in industry than in the service sector and European firms have the highest patent intensities, followed by companies in North America, Asia and the rest of the world. This correlation is also observed in the case of firms that file AMT patents; thus larger firms are filing more AMT patents than smaller ones.

Abstract

In this report the first results obtained from data provided by Fraunhofer Institute for Systems and Innovation Research (ISI) in the context of the Advanced Manufacturing for Competitiveness project are presented. The aims of this project are to develop and test a methodology based on patent analysis to assess the capacity of the EU Industrial R&D Scoreboard companies to develop advanced manufacturing technologies (AMTs) and key enabling technologies (KETs) which are expected to have a major impact on productivity, efficiency, profitability and employment in the major industrial sectors. The companies listed in the EU Industrial R&D Scoreboard hold a dominant position in KET and AMT filings accounting for about 61 % of total KET filings and 57 % of total AMT filings in 2011. European companies hold almost 50 % of the AMT worldwide patent filings and about 50 % of these are held by Germany headquartered companies. Japanese companies are responsible for 27 % of AMT filings worldwide and US companies for about 24 % of all transnational AMT patents. In KETs Japanese companies dominate the scene, followed by Europe and the USA. Developing and patenting AMTs and KETs seems to have become more expensive over the time period under study, as shown by the decrease in the average patent intensity since 2004. Although R&D expenditures and numbers of patent filings are significantly positively correlated with the number of employees, larger firms have lower patent intensities than smaller ones. In addition the patent intensity is higher in industry than in the service sector and European firms have the highest patent intensities, followed by companies in North America, Asia and the rest of the world. This correlation is also observed in the case of firms that file AMT patents; thus larger firms are filing more AMT patents than smaller ones. With regard to employment growth, however, we find no significant effect of KETs or AMTs filings. The largest shares of KETs filings are found in the Electronic & Electrical Equipment and Chemicals sectors. Firms in the Electronic & Electrical Equipment sector also account for the highest proportion of filings in AMT. However, the Industrial Engineering sector also accounts for large proportion, followed by the Automobiles & Parts and General Industrials sectors.

Keywords: patents, technological profile, KETS, AMT, R&D

1. Introduction

The contribution of the manufacturing sector to economic growth is considered of fundamental importance for boosting exports, generating added value and creating jobs all of which are necessary to address the current predicaments faced by the EU economy. Manufacturing companies in the EU in 2012 generated €EUR 1760 billion of value added and employed 30 million employees directly and approximately twice as that indirectly, mainly in small and medium-sized enterprises (SMEs)[1]. Manufacturing plays a key role in EU total exports, with a large trade surplus in manufactured

[1] http://ec.europa.eu/enterprise/policies/innovation/policy/amt/index_en.htm

products, estimated at €EUR 365 billion in 2012[2]. The industry is also investing heavily in innovation, accounting for almost 80 % of total private R&D investment[3] and manufacturing firms are almost three times more likely than service business to introduce not only new, innovative products but also new services[4].

EU manufacturing is now facing important challenges: despite the robust performance of certain sectors, such as mechanical engineering (in which European companies lead the world with a 37 % share of the global market), there has been a steady decline over recent years and the sector has been severely affected by the financial crisis of 2007- 8. The impact of the crisis on production was substantial and resulted in the loss of almost 3.8 million jobs. The proportion of value added attributable to manufacturing decreased during the crisis and has not yet fully recovered.

A globally competitive manufacturing sector is a priority not only in the EU, but also in all its main competitor regions, not least because the financial crisis of 2007- 8 led to recession in many developed countries. As a result, new initiatives to boost the competitiveness of the manufacturing sector are under way[5], with interest mainly focused on new technologies which rely more and more on information, automation, software and networking. Such technologies are expected to exploit and at the same time further enable the development of new production processes, novel materials and devices and applications with unprecedented functionality and capabilities. These new technologies are also expected to revolutionise the manufacturing of existing products by reducing the cost of production, the reliance on raw materials and the consumption of energy, while at the same time diminishing the adverse impact on the environment by reducing the generation of waste and pollution.

These new technologies which include digitisation of equipment and processes, three-dimensional printing, high-precision zero defect additive manufacturing and new processes and equipment which enable the development of novel functional materials with highly customised properties and the manipulation of matter at the atomic and sub atomic levels are collectively referred to as advanced manufacturing technologies (AMTs). AMTs are also expected to enable highly customisable, cost-effective, low-volume, flexible production by facilitating rapid integration of new processes, introduction of new features and changes in design.

In early 2013 the European Commission (EC) established the “Task Force on Advanced Manufacturing for Clean Production” to “foster the development and adaption of Advanced Manufacturing technologies by the European industry”. Advanced

[2] http://ec.europa.eu/eurostat/statistics-explained/index.php/Manufacturing_statistics_-_NACE_Rev._2
[3] http://iri.jrc.ec.europa.eu/scoreboard.html
[4] http://manufacturing.gov/advanced_manufacturing.html
[5] https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf

manufacturing is considered one of the core key enabling technologies[6] that are expected to play a key role in the upcoming industrial revolution. The aim of the Advanced Manufacturing for Competitiveness project is to develop and test the applicability of a methodology to assess the capability of companies to develop new innovative technologies for advanced manufacturing.

The aim of this study is to provide empirical evidence at the firm level about the role of AMTs and KETs and the impact of innovation in these technologies on the efficiency and productivity of companies across various industrial sectors and on employment in these sectors using data from the EU Industrial R&D Investment Scoreboard (the *Scoreboard*). The Scoreboard contains economic and financial data for the world's top companies ranked by their investments in research and development (R&D), (see Annex I). In this study the 2013 edition of the Scoreboard has been used.

The principal aim of this report is to describe the profile of the patent portfolios of the companies in the *Scoreboard*, to link their innovation output to input in terms of R&D expenditures and to draw useful conclusions about the policy implications at the level of the EU Member States. The data source for the input is the 2013 edition of the "EU Industrial R&D Investment Scoreboard" and the outputs are patent applications and further patent-related indicators at the transnational level from the the Worldwide Patent Statistical Database (PATSTAT) (see Annex I). 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 expenditure and patents in technology-based areas. Among companies in the *Scoreboard* there is a correlation between R&D expenditure and investment in innovation and innovation output, as measured by KET- and AMT-related transnational patent filings.

AMTs and KETs are core areas for achieving the strategic goals addressed in EU 2020. A number of initiatives from different directorates-general (DGs) such as the KETs Observatory and the Business Innovation Observatory are already under way. In this study 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, Annex II) are used in order to obtain results which are easily comparable. The focus, however, is on the firm-level data and the basic questions addressed are as follows: What firms are responsible for most of the patent filings in AMTs and KETs and which are the main industrial sectors responsible for patent filings within the two technology fields? Where have the R&D activities taken place? Which countries and which sectors are most actively inventing AMTs and KETs? Who owns the technologies or what does the ownership structure within AMTs and KETs look like? The focus will be on transnational patent filings

[6] https://ec.europa.eu/growth/tools-databases/ketsobservatory/

(Frietsch, Schmoch 2010), i.e. filings targeting international markets. In addition to the applicant information contained in patent filings, we will also make use of the inventor information to establish the location of the inventors that are most active in the area of KETs and AMTs. With regard to ownership, the headquarters location of the companies included in the *Scoreboard* is used.

2. Key enabling technologies and their importance

KETs are technologies associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly skilled employment. They are multidisciplinary, cutting across many technology areas with a trend towards convergence and integration. The following technologies are identified as KETs:

- Nanotechnology. This utilises methods of manipulating matter at a molecular/ atomic level in order to manufacture structures of a size of 100 nano metres or less.

- Photonics. This encompasses optical technology equipment such as lasers, lithography equipment, optical measurement systems, microscopes, lenses, optical communication, digital photography, light emitting diodes (LEDs) and organic LEDs (OLEDs), displays and solar cells.

- Industrial biotechnology. This focuses on enzymes, micro-organisms, amino acids and fermentation processes not related to the fields of medicine or agriculture.

- Advanced materials science. This covers a broad range of innovative materials including polymers, macromolecular compounds, rubber, metals, glass, ceramics, other non-metallic materials and fibres as well as the whole field of nano materials and speciality materials for electric or magnetic applications.

- Micro- and nano-electronics. This covers new technologies related to semiconductors, piezo-electrics and nano-electronics.

- Advanced Manufacturing Technologies for other KETs includes process and equipment technology that is used to produce any of the other five KETs. In the case of advanced materials, industrial biotechnology, nanotechnology and micro- and nano-electronics, such process technology typically relates to production apparatus, equipment and procedures for the manufacture of specific materials and components. In the case of photonics, process technology covers apparatus and equipment that is used to manufacture photonics products.

Building on 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 are promising new energy sources that convert chemical energy from a fuel, such as hydrogen or biogas, into electricity and can achieve a very high degree of efficiency.

- Digital information transmission. This field includes technologies for the transmission of digital information, such as telegraphic communication.

- Imaging physics. Imaging physics includes all pictorial communication, e.g. television, the transmission of pictures or their reproduction, scanning resolving and reproducing a picture.

- Dynamo- electric machines (electric motors): Dynamo- electric machines convert mechanical to electrical energy or vice versa by electromagnetic means.

- Biotechnology– Agro-food: Agro-food is defined as micro- organisms or enzymes and their composition as well as techniques for propagating, preserving and maintaining them. It includes undifferentiated animal and plant cells as well as methods for 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 the Fraunhofer Institute for Systems and Innovation Research (ISI) (Neuhäusler et al, 2015).

3. Results

The total number of transnational patents and the number of transnational patent filings related to KETs and AMTs over time are plotted in Figure 1. The general trends are similar in both fields with the number of KET filings increasing from approximately 32000 in the year 2000 to about 35000 in 2007 followed, by a slight decrease between 2008 and 2009. However, the number of transnational patents shows a similar trend, which is attributed to the financial crisis. From 2009 onwards, the number of filings in KETs rises very rapidly, up to about 41000 in 2011. AMT-related patents also increased between 2000 and 2007 from 6700 to 7500, then decreased the following year before increasing again after 2009 (Neuhäusler et al, 2015).

Over the period 2000-2011, although the absolute numbers of patent filings in KETs and AMTs increased, the proportion of total filings accounted for by these technology fields decreased because the total number of filings rose faster than the number of KET and AMT filings. In 2000, 20 % of total filings were related to KETs but by 2011 this figure had dropped to 18 %. The same is true for AMTs with the proportion of total filings that relate to AMTs falling from 4.2 % in 2000 3.5 % in 2011. Since then however, this overall trend, has been reversed as a result of the steep increase in AMT filings and especially in KETs filings, in recent years (Neuhäusler et al, 2015).

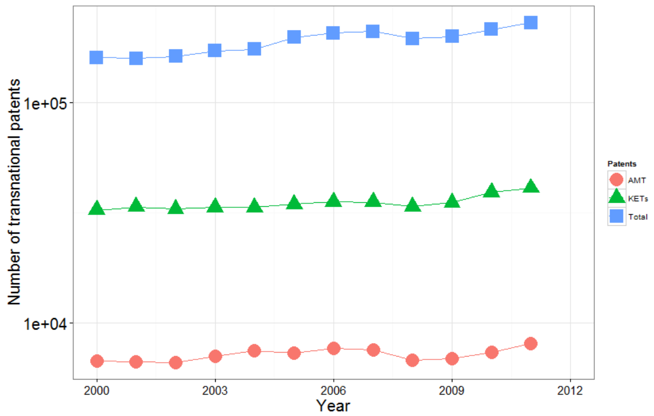

Figure 1 Total number of transnational filings and numbers of filings in KETs and AMTs.

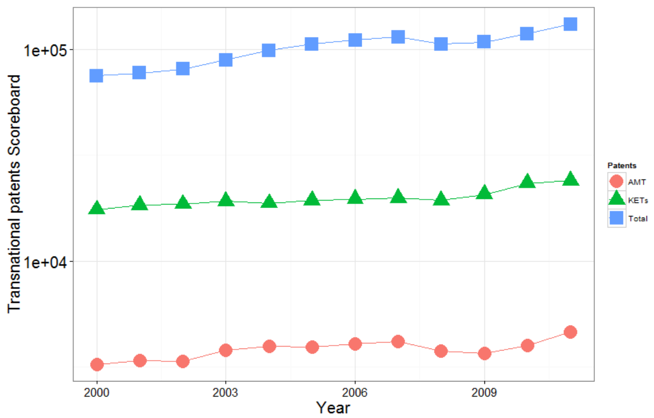

Figure 2 Total number of transnational filings and number of filings in KETs and AMTs from companies in the EU Industrial R&D Scoreboard

In 2011 the 2,670 matched *Scoreboard* firms (see Annex III) accounted for only a small proportion of the applicants in PATSTAT (about 2 %) but were responsible for 58 % of the transnational patents filed in that year. The remaining 42 % of patents were filed by universities or public research institutes, single inventors or firms that are not included in the *Scoreboard* (Neuhäusler, 2015). The *Scoreboard* companies are also responsible for the majority of transnational filings in KETs and AMTs accounting for, respectively, 61 % and 57 % of all transnational patent filings in these fields in 2011. To get a better idea of the number of patents filed by the firms listed in the 2013 EU Industrial R&D Scoreboard and their patent activities in KETs and AMTs, Figure 2, shows the total number of transnational filings, as well as the numbers of KET and AMT- related patents over time. The total number of transnational filings by the firms listed in the Scoreboard follows quite closely the general trends in patenting (Figure 1). The number of filings increased between 2000 and 2007, then decreased between 2008 and 2009, an effect that can be attributed to the economic crisis. Analysis of a sample of German firms, showed that this effect is due not only to a decrease in R&D expenditures during that period but also to cost-saving patent strategies adopted by 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, when *Scoreboard* firms filed about 130000 transnational patents.

It is further observed that the proportion of total filings that are KET and AMT patent filings drops over time (Neuhäusler et al, 2015). KET and AMT filings as a proportion of transnational patent applications filed by the *Scoreboard* firms followed a similar trend over the same period. This means that, on average, the rate of filing in these fields was slower than the rate of filing overall. If, however, we calculate the proportion of AMT-related filings which are filed by the *Scoreboard* companies and correlate this to the proportion of the total transnational filings by the *Scoreboard* companies we observe that they are positively correlated, i.e. patenting by Scoreboard companies in the field becomes more important over time. This is also true for KET related filings.

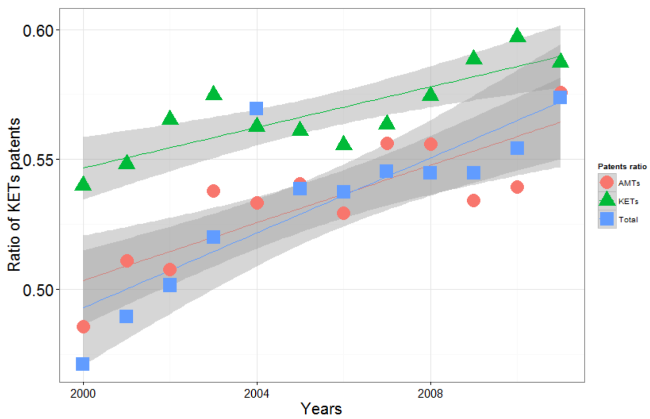

Figure 3 Proportion of KET and AMT related patents and proportion of total filings by Scoreboard companies between 2000 and 2011.

These results are summarised in Figure 3 where the proportion of filings by the *Scoreboard* companies between 2000 and 2011 are shown (blue squares) along with the proportion of KETs and AMTs filings by the same companies over the same period of time. The proportion of all transnational patents that come from *Scoreboard* companies has increased over time. Over the same time the contribution in KET and AMT-related patents also increased. At the same time, however, the patenting activities of the *Scoreboard* firms become broader.

KET filings, AMT filings and total filings at the transnational level by applicant location are shown in Figure 4 for the years 2000 and 2011. For clearer visibility, the countries have been categorised into four groups: Europe, North America, Asia and "Rest of the world". At this level of aggregation distinguishing between applicant and inventor location has a negligible effect on the result. Figure 4 shows that, among Asian companies included in the *Scoreboard* the proportion of total transnational filings that related to KETs rose from 38 % in 2000 to 59 % in 2011. In 2011, European and North American applicants were each responsible for 20 % of the total transnational patent applications. Only 1 % of KETs patents came from countries in the rest of the world. Interestingly, the picture looks totally different for AMTs, with European companies consistently dominating this area between 2000 and 2011. European applicants were responsible for 42 % of all transnational AMT filings in 2011, followed by applicants in Asia (34 %) and in North America (24 %). However, the progress made by Asian applicants is also reflected in their share of the total number of transnational patents which has rose from 30 % to 44 % over this period.

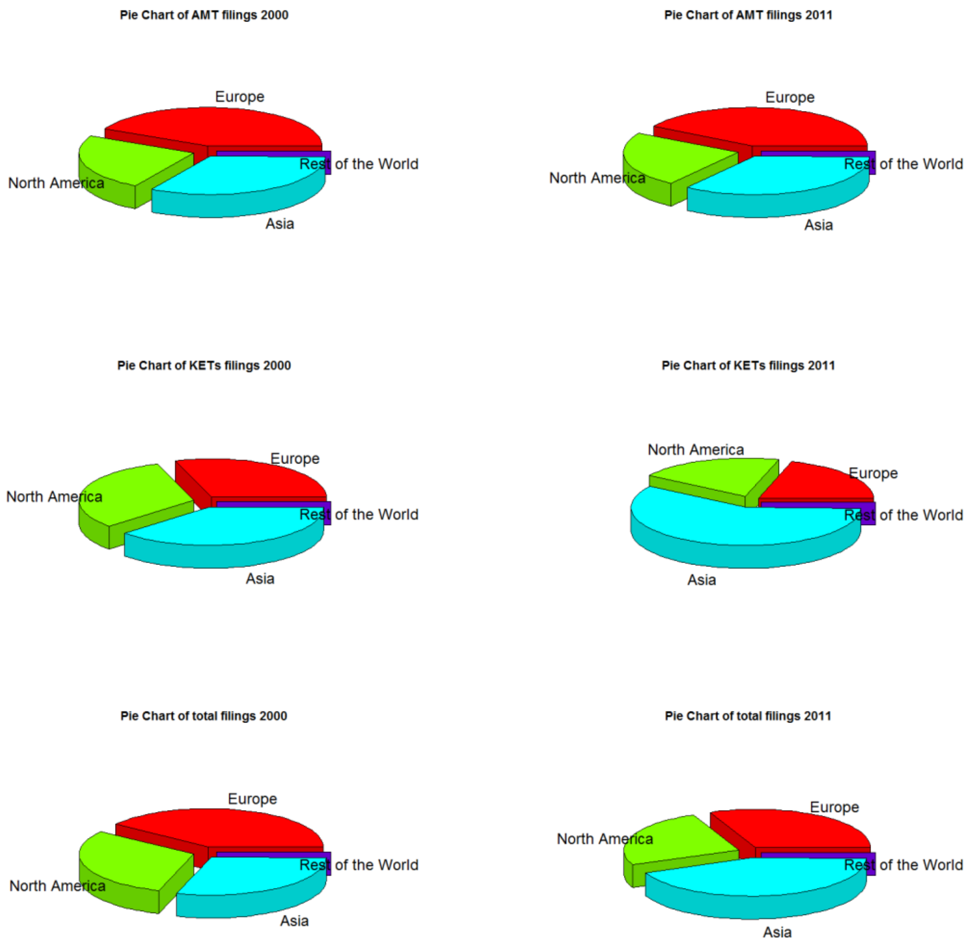

Figure 4 Share of AMTs, KETs and total patents according to applicant location in 2000 and 2011.

Looking in more detail of the contribution of the individual EU-28 Member States to AMT patenting over the period 2009- 2011 we find Germany and Austria-based companies at the top of the list with approximately 200 AMT patents per million employees. Using transnational patents per million employees rather than simply the number of patents ensures a better international comparability since the former metric is not influenced by the size of the workforce within the countries under analysis. Germany and Austria are closely followed by the Netherlands, Sweden, Denmark and

Finland with France and the United Kingdom ranking lower on this comparison (Figure 5). Germany and Austria-based companies also file the most KET patents per million employees in this case followed closely by the Netherlands, Finland, Belgium and Sweden (Neuhäusler, 2015).

Patent intensities or propensities are calculated from patent and R&D expenditure data and an assessment of the value of patent filings can be attempted using two indicators, the number of times a patent is cited in subsequent patent applications (patent forward citations) and the average patent family size. The number of patent forward citations is the indicator that is probably most commonly used to estimate the value of companies' patent filings or companies' patent portfolios (Narin et al. 1987; Trajtenberg 1990; Albert et al. 1991; Blind et al. 2009; Carpenter et al. 1981). The average number of forward citations in a four-year time window has been calculated and related to the number of patent filings from a particular company in a given priority year. The time window is necessary in order to avoid introducing a systematic bias favouring older patents (Neuhäusler, 2015). The average patent family size 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). Thus it first of all provides information about the internationalisation of a company's patent portfolio. However, it also tells us about the number of markets in which the applicant is seeking to secure in order to sell his invention.

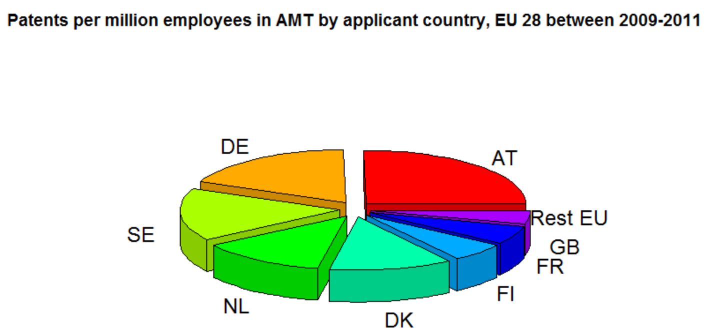

Figure 5 Share of AMT patents per million employees by applicant country from 2009 to 2011.

In 2007, the average number of citations a patent received from subsequent filings was 1.5. KETs patents are cited slightly more often than average with about 1.6 citations per filing. In contrast, AMT filings are cited less often than average, with only 1.15 filings per patent. The average family size is 5.1. This figure is somewhat lower for KETs and AMT filings with values below 4.9 (Neuhäusler, 2015).

Table 1 shows, in summary form, the profiles of the patent portfolios of the top 10 patenting firms in the 2013 R&D Scoreboard. With more than 3500 filings Panasonic accounted for largest number of transnational patent applications in 2011, followed by the Chinese firms Huawei and ZTE each with about 3000 filings. Patent intensities are quite similar with two notable exceptions: ZTE with 2.74 patents per million R&D expenditures and Sharp with 1.55 patents per million R&D expenditures. Patent value indicators in Table 1 show that filings from ZTE and Huawei are cited less frequently by subsequent patents than filings of the other companies of the list. In addition, the average family size of these two companies is smaller, implying that Huawei and ZTE file their patents in a smaller number of patent offices compared to the other companies of this top ten list. Finally in Table 1 information extracted from patent data about the location of the inventors, which provides hints about the internationalization of R&D activities of the companies, is presented.

Table 1 Profiles of the top 10 EU Industrial R&D Scoreboard companies by total transnational patent filings in 2011 (Neuhäusler, 2015).

Company Name		PANASONIC	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 expeditures (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
Patent Intensity per million R&D		**0.77**	**1.13**	**2.74**	**0.64**	**0.32**	**0.63**	**0.53**	**0.31**	**1.55**	**0.58**
Inventor location	Europe	2%	2%	0%	83%	4%	1%	83%	1%	2%	20%
	North America	1%	5%	1%	11%	4%	1%	8%	1%	2%	66%
	Asia	97%	92%	99%	4%	92%	98%	6%	98%	96%	14%
	ROW	0%	1%	0%	2%	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 member of fw citations (2006)		3.52	1.29	0.54	1.19	1.23	2.35	1.25	3.02	3.59	1.59

Table 2 Profiles of the top10 EU Industrial R&D Scoreboard companies (2013 edition) by total transnational patent filings in 2000.

Company Name		SIEMENS	PANASONIC	PHILIPS	SONY	ROBERT BOSCH	ERICSSON	ALCATEL-LUCENT	BAYER	GENERAL ELECTRIC	INFINEON TECHNOLOGIES
Country		DE	JP	NL	JP	DE	SE	FR	DE	US	DE
Transnational patent filings		2037	1906	1889	1655	1600	1277	1139	1079	1013	1003
Inventor location	Europe	94%	3%	89%	8%	95%	84%	56%	64%	11%	79%
	North America	5%	2%	5%	6%	4%	13%	42%	31%	83%	19%
	Asia	1%	95%	4%	86%	1%	2%	1%	4%	6%	1%
	ROW	0%	0%	2%	0%	0%	1%	1%	1%	0%	1%
Share of KETs filings in transnational filings		**9%**	**22%**	**23%**	**17%**	**9%**	**6%**	**19%**	**29%**	**20%**	**56%**
Share of AMT filings in transnational filings		**10%**	**4%**	**3%**	**3%**	**12%**	**12%**	**1%**	**1%**	**2%**	**3%**

In most cases inventors are based close to the location of the company headquarters. This is especially true for Asian-based companies with Hitachi, ZTE and Panasonic, for example, having over 97 % of their inventors located in Asia, implying that only a few of their patents are filed by foreign divisions of the company or subsidiaries. Of the companies in this list, General Electric shows the largest spread across countries in terms of inventors with only 66 % of the inventors located in North America where the headquarters of the company are also located. The remaining 34 % are split between Europe (20 %) and Asia (14 %). This large proportion of inventors in foreign countries is an indication that General Electric also carries out R&D in those countries. The other two companies with a wide spread of inventors across the world are both German firms, Robert Bosch and Siemens. In both cases, 83 % of their patents are filed by inventors from Europe, but inventors can also be found in North America, Asia and in the rest of the world. Interestingly, in the case of all the Asian firms in the list "home-based" inventors account for more than 90 % of patent filings, indicating that the R&D and patenting activities are less internationalized.

The performance of the firms of the 2013 edition of the *Scoreboard* over the period between 2000 and 2011 was further assessed[7]. In Table 2 the profiles of the patent portfolios of the top ten companies by total transnational patents in 2000 are presented. Siemens, Panasonic, Robert Bosch and General Electric also appear in this list. One thing to note is that all these companies have increased their patent output over the years. Another interesting observation is that Siemens, Robert Bosch and General Electric have more widespread R&D activities judging by the inventor location in 2011 compared to 2000. This is an indication of R&D activities which over time spread to other geographical areas through collaborations with research institutes, other companies or subsidiaries. Panasonic on the other hand files almost all its patents in Asia and this does not change over time. The presence of Chinese and Korean companies in the list of 2011 is also worth commenting.

Table 3 Profiles of the top 10 EU Industrial R&D Scoreboard companies by KETs transnational patent filings in 2011. Patent intensity, average family size and forward (fw) citations derived from KETs patents only (Neuhäusler, 2015).

Company Name		PANASONIC	SHARP	LG	FUJIFILM	SIEMENS	HITACHI	GENERAL ELECTRIC	PHILIPS	APPLIED MATERIALS	ROBERT BOSCH
Country		JP	JP	KR	JP	DE	JP	US	NL	US	DE
R&D expeditures (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
Transnational patent filings		904	734	598	490	479	447	374	346	335	301
Patent Intensity per million R&D		**0.20**	**0.54**	**n.a.**	**0.32**	**0.11**	**0.12**	**0.11**	**0.20**	**0.40**	**0.07**
Inventor location	Europe	0%	1%	0%	3%	83%	1%	13%	83%	12%	83%
	North America	1%	1%	0%	1%	11%	1%	72%	13%	86%	11%
	Asia	99%	98%	100%	96%	4%	98%	14%	4%	2%	4%
	ROW	0%	0%	0%	0%	2%	0%	1%	0%	0%	2%
Average family size (2006)		**4.24**	**3.98**	**4.99**	**4.37**	**4.06**	**4.46**	**4.54**	**6.00**	**4.94**	**4.04**
Average member of fw citations (2006)		3.50	4.01	2.77	2.95	1.21	3.28	1.56	3.34	0.91	1.17
Share of KETs filings in transnational filings		**26%**	**35%**	**55%**	**37%**	**18%**	**20%**	**19%**	**23%**	**86%**	**13%**

Table 3 shows the profiles of the top 10 *Scoreboard* companies in terms of KETs patent filings in 2011. Panasonic filed the largest number of transnational patents in KETs with 904 filings in 2011, followed by Sharp (734 filings) and LG (558 filings). Applied Materials with 86 % of their transnational filings in KET related fields has the largest share of KETs filings in its portfolio. The only other company in the top 10 list in which this share exceeds 50 % is LG. For the remaining companies, shares between 13 % and 37 % are observed. Patent intensities in KETs filings (KETs filings per million R&D expenditures of the firm in total) were also calculated and the highest value was

[7] Since we are based on the 2013 edition of the Scoreboard there might companies which were among the top R&D investors in one or more years between 2000 and 2011 but no longer appear in the latest editions of the Scoreboard. The performance of these firms is not taken into account.

observed in the case of Sharp. It should be kept in mind however that information on the exact amount of R&D expenditure on KETs is not available. Thus, KET patent intensity gives only a rough idea of the amount spent on KET filings per million total R&D expenditures and should be considered together with figures for KET filings as a proportion of total filings. The highest average number of forward citations can be found for Sharp, Panasonic and Philips. Thus, the two largest KET applicants also score highly in terms of quality of the patent portfolio, as measured by citations received from subsequent patents. Philips, however, has the largest average family size, i.e. the KETs patent portfolio of Philips is broadest in terms of markets covered.

Table 4 Profiles of the top 10 EU Industrial R&D Scoreboard companies (2013 edition) by KETs transnational patent filings in 2000.

Company Name		INFINEON TECHNOLOGIES	PHILIPS	APPLIED MATERIALS	PANASONIC	3M	BASF	BAYER	CORNING	SONY	DOW CHEMICAL
Country		DE	NL	US	JP	US	DE	DE	US	JP	US
Transnational KETs patent filings		561	427	425	416	354	327	310	304	280	260
Inventor location	Europe	79%	89%	89%	3%	5%	84%	72%	13%	5%	20%
	North America	19%	5%	5%	4%	88%	13%	26%	77%	1%	74%
	Asia	1%	4%	4%	93%	1%	2%	2%	6%	4%	3%
	ROW	1%	2%	2%	0%	6%	1%	0%	1%	90%	3%
Share of KETs filings in transnational filings		**56%**	**23%**	**90%**	**22%**	**59%**	**6%**	**29%**	**77%**	**17%**	**60%**
Share of AMT filings in transnational filings		**3%**	**3%**	**5%**	**4%**	**3%**	**12%**	**1%**	**2%**	**3%**	**0%**

Table 4 shows the profiles of the patent portfolios of the top ten *Scoreboard* companies (edition 2013) by total transnational patents in KETs in 2000. Philips, Panasonic and Applied Materials appear in both lists. In the case of Panasonic KETs related filings as a proportion of total filings has increased since 2000. This however is not the case for Philips and Applied Materials where the KET-related patents as a proportion of total patents has remained constant and slightly decreased in 2011 compared to 2000 respectively.

Table 5 Profiles of the top10 EU Industrial R&D Scoreboard companies by AMT transnational patent filings in 2011. Patent intensity, average family size and forward citations derived from AMT patents only are shown (Neuhäusler, 2015).

Company Name		SIEMENS	GENERAL ELECTRIC	ROBERT BOSCH	MITSUBISHI ELECTRIC	HITACHI	ABB	YASKAWA ELECTRIC	TOYOTA MOTOR	PANASONIC	HOENEYWELL
Country		DE	US	DE	JP	JP	CH	JP	JP	JP	US
R&D expeditures (in millions)		4278	3487	4242	1366	3612	1095	91	6829	4556	1364
Employees		402000	301000	302519	117314	323540	133600	8246	325905	330767	132000
Transnational patent filings		311	204	165	115	103	90	79	74	72	65
Patent Intensity per million R&D		**0.07**	**0.06**	**0.04**	**0.08**	**0.03**	**0.08**	**0.87**	**0.01**	**0.02**	**0.05**
Inventor location	Europe	86%	11%	78%	3%	2%	59%	0%	0%	0%	5%
	North America	12%	73%	16%	8%	4%	7%	0%	0%	3%	95%
	Asia	2%	14%	3%	89%	94%	11%	100%	99%	97%	0%
	ROW	0%	1%	2%	0%	0%	24%	0%	1%	0%	0%
Average family size (2006)		**4.15**	**4.97**	**4.08**	**4.68**	**3.92**	**4.75**	**4.33**	**5.14**	**4.61**	**3.35**
Average member of fw citations (2006)		1.16	1.58	1.12	1.43	2.11	1.46	2.25	2.44	3.15	0.64
Share of AMT filings in transnational filings		**11%**	**10%**	**7%**	**10%**	**5%**	**12%**	**53%**	**4%**	**2%**	**12%**

In Table 5 the profiles of the Top 10 performers in terms of AMT filings at the transnational level in 2011 are presented. The leading technology company in terms of AMT filings is Siemens with 311 AMT-related transnational filings in 2011. General Electric and Robert Bosch rank second and third with 204 and 165 filings, respectively.

The most highly cited AMT patent portfolios among the top 10 AMT firms are those of Panasonic, Toyota Motor and Yaskawa Electric, with Toyota Motor also the company with the highest average patent family size. AMT filings as a proportion of total filings are highest for Yaskawa Electric at 53 %. This result is corroborated by the patent intensity in AMTs of Yaskawa Electric, which is by far largest among the firms under comparison. With regard to the inventor locations, we once again find that the R&D activities of ABB, Siemens, General Electric and Robert Bosch are relatively widely scattered across the globe. It should be borne in mind once again that patent intensities are calculated from total R&D expenditure since it is not possible to determine the part of the investment that is targeted to AMTs.

Table 6 Profiles of the top 10 EU Industrial R&D Scoreboard companies (2013 edition) by AMT transnational patent filings in 2000.

Company Name		SIEMENS	ROBERT BOSCH	GENERAL ELECTRIC	HITACHI	PANASONIC	MITSUBISHI ELECTRIC	ABB	HONEYWELL	HONDA MOTOR	SONY
Country		DE	DE	US	JP	JP	JP	CH	US	JP	JP
Transnational AMT patent filings		200	190	90	74	72	71	69	63	56	54
Inventor location	Europe	90%	90%	2%	0%	3%	4%	75%	10%	2%	4%
	North America	5%	7%	98%	3%	2%	1%	10%	87%	3%	2%
	Asia	0%	0%	0%	97%	95%	95%	0%	2%	95%	92%
	ROW	5%	3%	0%	0%	0%	0%	15%	1%	0%	2%
Share of KETs filings in transnational filings		**9%**	**9%**	**20%**	**25%**	**22%**	**11%**	**15%**	**32%**	**6%**	**17%**
Share of AMT filings in transnational filings		**10%**	**12%**	**9%**	**9%**	**4%**	**10%**	**17%**	**13%**	**13%**	**3%**

In Table 6 the profiles of the patent portfolios of the top ten companies by total transnational patents in AMT in the year 2000 are presented. Seven companies (Siemens, Robert Bosch, General Electric, Hitachi, Panasonic, ABB and Honeywell) appear in both lists.

Table 7 presents the 10 top-performing companies in terms of filings of AMT and KET-related patents each year between 2001 and 2010 in columns 1 and 2 respectively. The third column of Table 7 shows the top 10 performers in filing transnational patent applications every year over the same period. It is interesting to note that the list of companies which hold the lion's share of AMT and KET filings is limited. In the case of AMT filings, Siemens and Robert Bosch from Germany, General Electric and Honeywell from the USA, Hitachi and Panasonic from Japan and finally ABB from Switzerland appear in the top- 10 list in every year between 2001 and 2010. Hitachi and Panasonic from Japan also perform quite well in terms of KET-related filings. The list of companies which have filed extensively in KETs during this period also includes Philips, Fujifilm, Sharp, Konica Minolta, BASF, 3M, Infineon Technologies and LG. Unsurprisingly, most of these companies also appear in the final column of the table, which shows the 10 top-performing companies in transnational filings during the period between 2001 and 2010. This is linked to the initial observations that AMTs and to a lesser extent KETs are being developed mainly by large companies that are included in the *Scoreboard* and possess the resources which are necessary for the development of this type of technology. However, one should interpret these results cautiously because as previously stated the study is based on the 2013 edition of the EU Industrial R&D

Scoreboard and there might be companies which were among the top R&D performers in the past but no longer appear in the *Scoreboard*. As a result these companies are excluded from our analyses.

There is also evidence derived from patent intensity and R&D expenditure data that innovating in these technological fields has become more and more expensive over the years. The average patent intensity per million R&D for the *Scoreboard* companies was 0.36 patents per million in 2011 a decrease since 2004 (Neuhäusler, 2015). This trend is surprising because during the 1990s patent intensities were growing fast (Blind et al. 2006). Since the total number of patents increases over time this could be due to an increase in R&D complexity and cost or due to an overall structural change towards more R&D intensive or more expensive research fields.

Table 7 Rankings of companies by number of KET, AMT and total transnational patents from 2001-2010.

year	Top 10 companies by AMT filings		Top 10 companies by KETs filings		Top 10 companies by total filings	
2010	SIEMENS	278	PANASONIC	1002	ZTE	3372
2010	ROBERT BOSCH	138	SHARP	972	PANASONIC	3163
2010	GENERAL ELECTRIC	115	FUJIFILM	574	SIEMENS	2298
2010	HITACHI	85	HITACHI	551	HITACHI	2104
2010	PANASONIC	83	LG	525	SHARP	1971
2010	MITSUBISHI ELECTRIC	82	SUMITOMO CHEMICAL	475	ROBERT BOSCH	1962
2010	ABB	70	KONICA MINOLTA	419	SAMSUNG ELECTRONICS	1832
2010	MITSUBISHI HEAVY	69	APPLIED MATERIALS	367	TOYOTA MOTOR	1795
2010	ILLINOIS TOOL WORKS	61	DOW CHEMICAL	363	LG ELECTRONICS	1728
2010	HONEYWELL	59	PHILIPS	351	QUALCOMM	1604
2009	SIEMENS	260	SHARP	803	ZTE	2804
2009	ROBERT BOSCH	159	PANASONIC	738	PANASONIC	2771
2009	GENERAL ELECTRIC	105	FUJIFILM	475	ROBERT BOSCH	1977
2009	ABB	83	PHILIPS	434	SIEMENS	1938
2009	PANASONIC	80	SUMITOMO CHEMICAL	376	QUALCOMM	1784
2009	HITACHI	63	HITACHI	367	LG ELECTRONICS	1747
2009	MITSUBISHI ELECTRIC	61	DUPONT	359	SAMSUNG ELECTRONICS	1634
2009	HONEYWELL	61	BASF	354	HUAWEI	1621
2009	CONTINENTAL	61	LG	352	PHILIPS	1601
2009	TOYOTA MOTOR	56	KONICA MINOLTA	351	SHARP	1583
2008	SIEMENS	291	PANASONIC	530	PANASONIC	2332
2008	ROBERT BOSCH	181	SHARP	498	SIEMENS	2039
2008	GENERAL ELECTRIC	96	APPLIED MATERIALS	454	ROBERT BOSCH	1914
2008	HONEYWELL	94	PHILIPS	395	HUAWEI	1755
2008	ABB	91	FUJIFILM	391	QUALCOMM	1720
2008	CONTINENTAL	84	SUMITOMO CHEMICAL	389	PHILIPS	1716
2008	EADS	58	BASF	352	ERICSSON	1492
2008	PANASONIC	56	KONICA MINOLTA	320	LG ELECTRONICS	1487
2008	MITSUBISHI ELECTRIC	47	DUPONT	315	NEC	1429
2008	UNITED TECHNOLOGIES	47	3M	312	SONY	1410
2007	SIEMENS	273	KONICA MINOLTA	428	PANASONIC	2194
2007	ROBERT BOSCH	200	PHILIPS	427	SIEMENS	2136
2007	CONTINENTAL	116	PANASONIC	410	HUAWEI	2053
2007	HONEYWELL	94	SHARP	388	ROBERT BOSCH	1978
2007	ABB	83	FUJIFILM	360	SAMSUNG ELECTRONICS	1853
2007	GENERAL ELECTRIC	78	DUPONT	335	FUJITSU	1765
2007	TOYOTA MOTOR	75	SUMITOMO CHEMICAL	328	PHILIPS	1742
2007	UNITED TECHNOLOGIES	68	BASF	311	TOYOTA MOTOR	1679
2007	FANUC	68	NEC	307	LG ELECTRONICS	1601
2007	FUJITSU	64	APPLIED MATERIALS	305	SONY	1515
2006	SIEMENS	276	PHILIPS	493	SAMSUNG ELECTRONICS	2486
2006	ROBERT BOSCH	147	PANASONIC	435	SIEMENS	2442
2006	ABB	134	TOKYO ELECTRON	390	PANASONIC	2288
2006	HONEYWELL	122	KONICA MINOLTA	367	PHILIPS	2014
2006	GENERAL ELECTRIC	74	SHARP	312	HUAWEI	1708
2006	FANUC	74	DUPONT	309	ROBERT BOSCH	1661
2006	UNITED TECHNOLOGIES	64	SIEMENS	305	FUJITSU	1560
2006	PANASONIC	59	FUJIFILM	295	NOKIA	1474
2006	FUJITSU	57	CORNING	292	TOYOTA MOTOR	1458
2006	HITACHI	56	BASF	276	LG ELECTRONICS	1370
2005	SIEMENS	268	PHILIPS	522	PHILIPS	2674
2005	HONEYWELL	147	FUJIFILM	512	PANASONIC	2673
2005	ROBERT BOSCH	134	PANASONIC	454	SIEMENS	2544
2005	FANUC	97	BASF	359	SAMSUNG ELECTRONICS	2136
2005	TOYOTA MOTOR	83	TOKYO ELECTRON	299	ROBERT BOSCH	1586
2005	ABB	75	3M	298	LG ELECTRONICS	1482
2005	PANASONIC	73	KONICA MINOLTA	283	SONY	1267
2005	GENERAL ELECTRIC	72	GENERAL ELECTRIC	282	FUJITSU	1251
2005	HONDA MOTOR	72	FUJITSU	281	BASF	1205
2005	EADS	58	DUPONT	272	TOYOTA MOTOR	1192
2004	SIEMENS	267	PHILIPS	665	PHILIPS	3011
2004	ROBERT BOSCH	133	PANASONIC	473	PANASONIC	2885
2004	FANUC	121	DUPONT	417	SIEMENS	2417
2004	HONEYWELL	99	FUJIFILM	304	SAMSUNG ELECTRONICS	2062
2004	PANASONIC	94	BASF	266	ROBERT BOSCH	1491
2004	HONDA MOTOR	91	EASTMAN KODAK	266	SONY	1429
2004	UNITED TECHNOLOGIES	72	3M	253	LG ELECTRONICS	1333
2004	PHILIPS	69	TOKYO ELECTRON	244	NOKIA	1131
2004	EADS	66	HITACHI	232	JOHNSON & JOHNSON	1011
2004	ABB	62	APPLIED MATERIALS	231	BASF	993
2003	SIEMENS	236	PHILIPS	569	PHILIPS	2873
2003	FANUC	115	PANASONIC	531	PANASONIC	2529
2003	ROBERT BOSCH	104	DUPONT	384	SIEMENS	2201
2003	PANASONIC	101	3M	373	SAMSUNG ELECTRONICS	1670
2003	HONEYWELL	96	CANON	342	SONY	1540
2003	GENERAL ELECTRIC	70	INFINEON TECHNOLOGIES	293	ROBERT BOSCH	1231
2003	HONDA MOTOR	68	FUJITSU	288	FUJITSU	1209
2003	ABB	64	HITACHI	285	NOKIA	970
2003	HITACHI	53	SAMSUNG ELECTRONICS	283	HITACHI	951
2003	PHILIPS	52	EASTMAN KODAK	282	LG ELECTRONICS	941
2002	SIEMENS	203	PHILIPS	636	PHILIPS	2964
2002	ROBERT BOSCH	112	PANASONIC	410	PANASONIC	2032
2002	HONEYWELL	70	CANON	377	SIEMENS	2026
2002	HONDA MOTOR	67	INFINEON TECHNOLOGIES	370	SONY	1365
2002	PHILIPS	65	DUPONT	341	ROBERT BOSCH	1335
2002	PANASONIC	59	BASF	317	SAMSUNG ELECTRONICS	1136
2002	GENERAL ELECTRIC	59	TOKYO ELECTRON	307	FUJITSU	1020
2002	DELPHI	57	EASTMAN KODAK	306	NOKIA	983
2002	ABB	56	3M	304	BAYER	948
2002	FANUC	55	SONY	291	BASF	942
2001	SIEMENS	248	PHILIPS	553	PHILIPS	2690
2001	ROBERT BOSCH	150	3M	416	SIEMENS	2225
2001	PHILIPS	78	INFINEON TECHNOLOGIES	394	PANASONIC	1708
2001	HITACHI	74	PANASONIC	372	ROBERT BOSCH	1642
2001	HONDA MOTOR	73	CORNING	310	SONY	1369
2001	HONEYWELL	68	BASF	302	NOKIA	1079
2001	PANASONIC	66	APPLIED MATERIALS	293	BAYER	1065
2001	ABB	61	CANON	293	ERICSSON	971
2001	MITSUBISHI ELECTRIC	59	SONY	284	BASF	963
2001	GENERAL ELECTRIC	52	TOKYO ELECTRON	279	ALCATEL-LUCENT	876

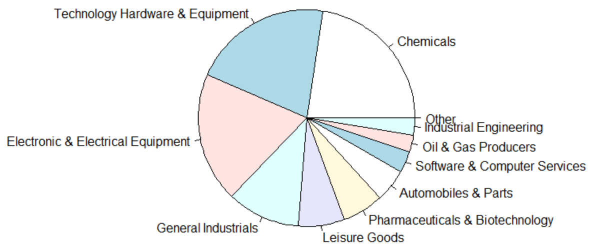

Figure 6 KETs patent filings by sectors (ICB 3-digit), from firms in the EU Industrial R&D Scoreboard (edition 2013) between 2000-2012

Most of the KETs patents that have been filed by *Scoreboard* companies between 2000 and 2012 were filed by companies in the Technology Hardware & Equipment sector, in the Chemicals sector and in the Electronics and Electrical Equipment sector, followed by General Industrialists as shown in Figure 6 where classification to sectors has been based on the ICB classification scheme at the three digit level. Differentiating the ICB at the 4-digit level shows that the largest share on total patent filings between 2000 and 2012 comes from companies in the Chemicals sector followed by companies in the Electronic Equipment and in the Semiconductors sectors (Figure 7).

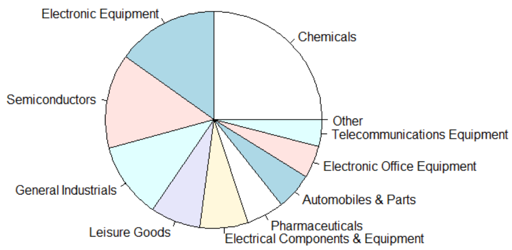

Figure 7 KETs patent filings by sectors (ICB 4-digit), from firms in the EU Industrial R&D Scoreboard (edition 2013) between 2000-2012

In the case of the AMT related patent filings over the same period it is observed that companies from the subsectors Electronic & Electrical Equipment, Automobiles & Parts and Industrial Engineering and General Industrials are responsible for more than 50 % of the total filings (Figure 8).

Finally in Figure 9 the classification of AMT related patents that were filed by *Scoreboard* companies over the period between 2000 and 2012 based on the ICB classification scheme at the 4 digit level is presented. The lion share of filings at this level comes from companies in the Automobiles and Parts subsector. The contribution of companies from the Industrial Machinery, Electrical Components & Equipment, Electronic Equipment and General Industrials subsectors is significant.

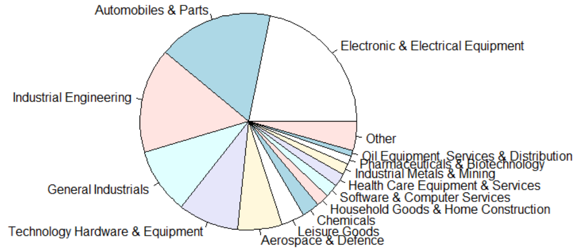

Figure 8 AMT patent filings by sectors (ICB 3-digit), from firms in the EU Industrial R&D Scoreboard (edition 2013) between 2000-2012

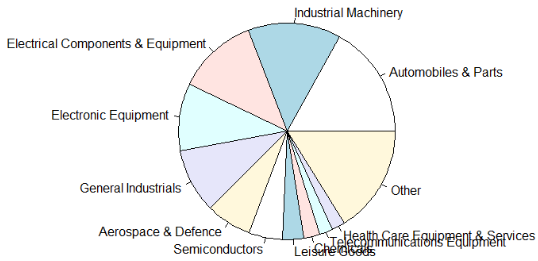

Figure 9 AMT patent filings by sectors (ICB 4-digit), from firms in the EU Industrial R&D Scoreboard (edition 2013) between 2000-2012

In Table 8 the lists of the top ten performing Scoreboard companies within the specific exemplary technologies (Imaging physics, digital communications, agro food, fuel cells and electric motors) are presented. These technologies are linked to KETs and AMT applications and it is thus not surprising that companies which excel in filing patents in these technologies are companies which appear in the top ten lists in Table 7 as well.

Table 8 Top 10 companies in transnational patents within the specific technologies between 2000-2012.

	Imaging Physics		Digital Communications		Agro Food		Fuell Cell		Electric Motors	
	Company	patents	Company	patents	Company	patents	Company	patents	Company	patents
1	PANASONIC	4608	HUAWEI	6036	BASF	609	TOYOTA MOTOR	740	ROBERT BOSCH	992
2	SONY	4586	ERICSSON	5445	DUPONT	512	PANASONIC	368	SIEMENS	924
3	SAMSUNG ELECTRONICS	3652	NOKIA	5201	BAYER	417	HONDA MOTOR	301	MITSUBISHI ELECTRIC	382
4	PHILIPS	3080	ALCATEL-LUCENT	4919	MONSANTO	341	NISSAN MOTOR	293	TOYOTA MOTOR	328
5	TECHNICOLOR	2698	QUALCOMM	4343	SYNGENTA	224	UNITED TECHNOLOGIES	257	HITACHI	322
6	CANON	2246	ZTE	3672	ROCHE	167	TOSHIBA	154	GENERAL ELECTRIC	284
7	LG ELECTRONICS	2051	SAMSUNG ELECTRONICS	3282	DOW CHEMICAL	139	GENERAL MOTORS	140	PANASONIC	258
8	SHARP	1820	SIEMENS	2925	MERCK US	136	SIEMENS	121	VALEO	257
9	EASTMAN KODAK	1013	PANASONIC	2833	PFIZER	133	SONY	117	LG ELECTRONICS	187
10	FUJIFILM	964	LG ELECTRONICS	2149	GLAXOSMITHKLINE	126	SAMSUNG SDI	110	ALSTOM	183

Finally a number of econometrics models and regressions have been performed by Fraunhofer ISI (Neuhäusler, 2015) in order to assess the effect of various parameters on patent intensity. 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. Controlling for sector and country specific effects, a significantly negative coefficient for the firm size variable was found, 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.

4. Conclusions

In this report the first results of the project on Advanced Manufacturing for competitiveness are summarised. The aim of the project was to link R&D expenditures to patent-related indicators in order to be able to assess the competitiveness and productivity of the largest R&D performers in developing AMTs and KETs.

The companies listed in the 2013 edition of the EU Industrial R&D Scoreboard were responsible for more than half of the KET and AMT related transnational patents that have been filed in 2011. The *Scoreboard* firms are the top R&D investors in the world although they represent only 2 % of all patent applicants in 2011, and thus hold a dominant position in KETs and AMTs filings. The absolute numbers of patent filings in KETs and AMTs have increased over time but the KETs' and AMTs' shares of total filings have decreased, implying that growth of KET and AMT filings over the period 2000-2011 was below average. This trend also holds true for the firms that are listed in the *Scoreboard* their contribution however in total transnational patents and in KET and AMT related filings becomes more important over time.

European companies hold almost 50 % of the AMT related patent filings, and about 50 % of these come from Germany-based companies. Japan-based companies are responsible for 27 % of AMT filings worldwide and US companies for about 24 % of all transnational AMT patents. In the case of KETs, it is Japan and Asia in general that clearly dominate the scene, followed by Europe and the USA. Over the period under study companies based in Asia, especially in Japan, have increased their share in KET related filings from 38 % in 2000 to 59 % in 2011 and in transnational patent filings from 30 % in 2000 to 44 % in 2011. In this case, the technological contribution of Europe is more widespread, with Germany again leading, but more closely followed by France, the UK and the Netherlands.

Another useful indicator in addition to the absolute number of filings is the patent intensity which is defined as the number of filings per million R&D expenditures.

Average patent intensity has decreased since 2004 and this is also the case for KETs and AMTs, showing that R&D expenditures have grown faster than patent filings over this period. Larger firms have lower patent intensities than smaller ones and the patent intensity is higher in industry than in the service sector. European firms have the highest patent intensities followed by North American companies, Asian companies and companies from the rest of the world. R&D expenditures and patent filings are significantly positively correlated with the number of employees. A positive correlation with the number of employees is also found for firms which have filed AMT patents. This implies that larger firms are filing more AMT-related patents than smaller ones. With regard to employment growth, however, we find no significant effect of KET or AMT filings.

We further attempted to distinguish KET and AMT filings by economic sectors. The highest proportions of KET-related filings can be found in the *Electronic & Electrical Equipment* and *Chemicals* sectors*.* Firms in the *Electronic & Electrical Equipment* sector are also responsible for the largest proportions of AMT filings. However, the *Industrial Engineering* sector also accounts for a high proportion, followed by the *Automobiles & Parts* and *General Industrials* sectors*.*

Finally, the study has provided analyses of patent filings of firms listed in the EU Industrial R&D Scoreboard in specific technology fields that are related to KETs and AMTs. Among the technologies in the comparison, *Digital Information Transmission* is the largest technology with 40805 transnational filings in total from 2000 to 2011, followed by *Imaging Physics* and *Electric Motors*. The two smallest technologies within this comparison are *Fuel Cells* and *Agro-food* with less than 3000 patents in total from 2000 to 2011*.*

Based on these findings it is evident that European companies do invest in KETs and in particular in AMTs, because it seems that these technologies are considered vital for maintaining current competitiveness. Other countries, however, and especially Japan, also invest heavily 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. For policy makers in Europe these findings have two important implications. First, efforts to keep up with Japanese companies should not be reduced. And second, a strategy aiming at finding a suitable position in global value- and innovation chains and selectively augmenting existing capabilities might be more appropriate than attempting to attain a general technological leading position in all KETs. Europe’s dominance in AMTs is such a strength that could be extended. The considerable concentration of AMT capabilities in Germany and a few other large countries in Europe offers the economies of scale and scope that are not yet present to the same extent for the rest of the other KETs. A broadening of the basis as well as network effects within Europe might be a worthwhile goal to strive for.

References

Albert M.B., Avery D., Narin F. and McAllister P. (1991): Direct validation of citation counts as indicators of industrially important patents. *Research Policy*, 20, 251-259.

Baeza-Yates R. and Ribeiro-Neto B. (2011): *Modern Information Retrieval - The concepts and technology behind*: Pearson Education Limited.

Blind K., Cremers K. and Mueller E. (2009): The Influence of Strategic Patenting on Companies' Patent Portfolios. *Research Policy*, 38, 428-436.

Blind K., Edler, J., Frietsch R. and Schmoch U. (2006): Motives to patent: Empirical evidence from Germany. *Research Policy*, 35, 655-672.

Carpenter M.P., Narin F. and Woolf P. (1981): Citation rates to technologically important patents. *World Patent Information*, 3, 160-163.

Du Plessis M., Van Looy B., Song X. and Magerman T. (2009): *Data Production Methods for Harmonized Patent Indicators: Assignee sector allocation* (EUROSTAT Working Paper and Studies). Luxembourg.

Freeman C. (1982): *The Economics of Industrial Innovation*. London: Pinter Publishers.

Frietsch R. (2007): *Patente in Europa und der Triade - Strukturen und deren Veränderung* (Studien zum deutschen Innovationssystem No. 9-2007). Berlin: Bundesministerium für Bildung und Forschung.

Frietsch R. and Schmoch U. (2010): Transnational Patents and International Markets. *Scientometrics*, 82, 185-200.

Grupp H. (1998): *Foundations of the Economics of Innovation - Theory, Measurement and Practice*. Cheltenham: Edward Elgar.

IDEA Consult, ZEW, TNO, CEA (2012): Feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies: Report for the European Commission, DG Enterprise and Industry.

Magerman T., Grouwels J., Song X. and Van Looy B. (2009): *Data Production Methods for Harmonized Patent Indicators: Patentee Name Harmonization* (EUROSTAT Working Paper and Studies). Luxembourg.

Martinez C. (2011): Patent families: When do different definitions really matter? *Scientometrics*, 86, 39-63.

Narin F., Noma, E. and Perry R. (1987): Patents as indicators of corporate technological strength. *Research Policy*, 16, 143-155.

Neuhäusler P., Frietsch R. and Rothengatter O. (2014): *Patent Applications - Structures, Trends and Recent Developments 2013*. Berlin: Expertenkommission Forschung und Innova-tion (EFI).

Neuhäusler P., Frietsch R., Bethke N., Mund C. (2015): *Assessing companies' capability to develop advanced manufacturing technologies in selected industrial sectors.* JRC/SVQ/2014/J.2/0009/NC, Final Report. Fraunhofer Institute for Systems and Innovation Research ISI

Peeters B., Song X., Callaert J., Grouwels J. and Van Looy B. (2009): *Harmonizing harmonized patentee names: an exploratory assessment of top patentees* (EUROSTAT Working Paper and Studies). Luxembourg.

Putnam J. (1996): *The value of international patent rights*. Yale: Yale University.

Raffo J. and Lhuillery S. (2009): 'How to play the "Names Game": Patent retrieval comparing different heuristics. *Research Policy*, 38, 1617-1627.

Schmoch U., Grupp H., Mannsbart W. and Schwitalla B. (1988): *Technikprognosen mit Patentindikatoren*. Köln: TÜV Rheinland.

Trajtenberg M. (1990): A penny for your quotes: patent citations and the value of innovation. *Rand Journal of Economics*, 21, 172-187.

Van Rijsbergen C.J. (1979): *Information Retrieval*. London, Boston: Butterworths.

WIPO (2006): *International Patent Classification: Core Level*, Eighth Edition, Volume 5: World Intellectual Property Organization (WIPO).

Witten I.H. and Eibe F. (2014): *Data Mining. Practical Machine Learning Tools and Techniques. San Diego, Los Angeles: Elsevier Science & Technology Books.*

Annex I

In this annex the data used for the study are described. Company-specific data such as employment and R&D expenditure come from the EU Industrial R&D Scoreboard, whereas patent data are based on the "EPO Worldwide Patent Statistical Database" (PATSTAT). The matching procedure which is necessary for linking the PATSTAT entries with the Scoreboard companies is briefly presented.

PATSTAT

PATSTAT is a relational database which is updated twice a year and contains information about published patents from 83 patent authorities worldwide, dating back to the late 19th century. All information that is provided on a patent application is included in the corresponding PATSTAT entry. Within the original version of the database, the names of the applicants are in a "raw format" taken directly from the patent application, which means that several variants of the same name may exist. The names may also contain special characters, abbreviations, legal forms, and spelling mistakes. The automated harmonization of all applicant names occurring 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 process of name harmonization includes cleaning-up of special characters (HTML code, accents, etc.) and punctuation , cleaning-up of legal forms (e.g. Inc., Ltd., GmbH), harmonisation of additional enterprise information ("COMPANY", "CORP", "CORPORATION"), harmonisation of spelling variants ("SYSTEM", "SYSTEMS", "SYSTEMES"), condensation of irrelevant characters ("3 COM", "3COM") and umlaut harmonization (see Annex III for more details). 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 this analysis are counted according to their year of worldwide first filing, commonly known as the priority year, which is closest to the date of invention. In order to overcome the home advantage of domestic applicants, all applications that are filed according to the patent cooperation treaty (PCT), whether or not they were transferred to the European Patent Office (EPO), are counted along with all applications which are directly filed at EPO without a precursor PCT application, as suggested by Frietsch and Schmoch (2010). The data from the PATSTAT database were matched at the level of patent applicants in the harmonized version with data from the EU Industrial R&D Scoreboard at the level of individual companies (including subsidiaries).

The EU Industrial R&D Investment Scoreboard

The EU Industrial R&D Scoreboard (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 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 about where R&D is actually performed, the whole R&D investment of *Scoreboard* companies is attributed to the country in which that company has its registered office. The *Scoreboard* data are primarily of interest to those concerned with benchmarking company commitments and performance (e.g. companies, investors and policymakers).

The scope of the *Scoreboard* is gradually being improved, by 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 more fast-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. 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, capital expenditures, operating profits and number of employees are collected following the same methodologies, definitions and assumptions as applied in previous years. This ensures comparability so that the companies' economic and financial data can be analysed over a longer period of time. For the second consecutive year, data are now being collected (by Bureau van Dijk Electronic Publishing GmbH) following basically the same approach and methodology applied since the first edition of the *Scoreboard*.

In the 2013 edition of the *Scoreboard*, companies' R&D rankings are based on information taken from their latest published accounts. In the case of most companies, this corresponds to calendar year 2012, but in a significant proportion of companies the financial year ended on 31 March 2013. In few of the included companies included the financial years end as late as the end of June 2013 and a in a few cases only accounts to end- 2011 were available.

Annex II

KETs and AMTs related International Patent Classification codes

The IPC is a hierarchical classification system used primarily to classify and search patent documents according to the technical fields they pertain. The classification scheme contains about 70000 entries identified by classification symbols (IPC codes) that can be allotted to patent documents. These different classification places are arranged in a tree-like, hierarchical structure. The IPC is updated annually and revised every three years to capture technological changes more effectively. Existing data are adjusted to the current version of the IPC (WIPO 2006, Frietsch 2007).

For consistency with existing figures for patents relating to KETs and AMTs, we resort to the most recent definition of KETs that has been developed by the KETs Observatory, in which AMTs is a subfield of KETs (IDEA Consult et al. 2012). The definition is based on the (IPC).

Micro Nano electronics	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, H015K 3, 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
Photonics	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, 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, except for co occurence with G02B 61, G02B 63, G02B 66/36, G02B 66/38, G02B 66/40, G02B 66/44, G02B 66/46
Industrial Biotechnology	C02F 3/34, C07C 29, C07D 475, C07K 2, C08B 3, C08B 7, C08H 1, C08L 89, C09D 11, C09D 189, C09J 189, C12M, C12P, C12Q, C12S, G01N 27/327 except for co-occurrence with A01, A61, C07K 14/435, C07K 14/47, C07K 14/705, C07K 16/18, C07K 16/28, C12N 15/09, C12N 15/11, C12N 15/12, C12N 5/10, C12P 21/08, C12Q 1/68, G01N 33/15, G01N 33/50, G01N 33/53, G01N 33/68, G01N 33/566, C12N 1/19, C12N 1/21, C12N 1/15, C12N 15/00, C12N 15/10, C12P 21/02
Advanced Materials	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
Nanotechnology	B81C, B82B, B82Y
Advanced Manufacturing Technologies	B03C, B06B 1/6, B06B 3/00, B07C, B23K, B23P, B23Q, B25J, G01D, G01F, G01H, G01L, G01M, G01P, G01Q, G05B, G05D, G05F, G05G, G06M, G07C, G06 if co occurence 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, B21B, 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, F16B, G01K, H05H, G08C except for co occurence 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

Annex III

In this annex a short description of the three steps in the name-matching procedure (initial data cleaning, calculation of similarity scores and the selection of the matched entries) is provided.

Data cleaning

In this step both the applicant names from PATSTAT and the company names from the EU Industrial R&D Scoreboard are cleaned by the same procedure to ascertain conformity. All text strings are converted to lowercase letters and umlauts are replaced by the corresponding vowel. Special characters are replaced by a single space and all occurrences of multiple spaces are replaced by a single space. In that way, we avoid incorrect assemblies of words that are separated only by a special character, particularly those separated by an “&”.

Next, text strings denoting the legal form of the companies are removed. The list used to detect legal forms contains internationally applicable notations as well as country-specific forms. Thus, deletion of abbreviations that might have a legal meaning in one country but not in others is avoided.

Finally, country and city names are removed from the company names if they occur at the end of the company name. This is to prevent removal of the name of a country that is an essential part of the company name, for example as in "France Telecom". In this step, the country assigned to the company/applicant is also compared with the one mentioned in the text string to avoid potential errors.

Calculation of similarity scores

For the computation of the similarity scores, a variant of the Levenshtein distance is applied. The Levenshtein distance is obtained from the number of edits needed to align two text strings. By dividing by the number of characters in the longer of the two text strings and subtracting from 1, the resulting values of the similarity function are normalised between 0 and 1. The lower the number of edits necessary to align two text strings, the higher the similarity between the two.

An entry in PATSTAT is considered a match to a *Scoreboard* entry only if a predetermined similarity threshold value "*t*" is exceeded. In order to determine this threshold a manually matched random set of 100 company names and 100 subsidiary names is used as the "golden standard". Multiple assignments of PATSTAT to *Scoreboard* entries are allowed. These matches are then stored in a separate table in the PATSTAT database for further use. The basic indicators for matching are:

- Recall or true positive rate: the proportion of true matches that have been correctly identified in the total number of positive elements (true positives (TP) and false negatives (FN)) = TP/(TP+FN).
- Precision or positive predictive value: the proportion of true matches that have been correctly identified in the total number of elements identified as positive (true positives and false positives (FP)) = TP/(TP+FP).
- F-Score: the harmonic mean of recall and precision. Increasing the Recall usually leads to reduction in the Precision (Baeza-Yates 2011; Raffo and Lhuillery 2009; van Rijsbergen 1979; Witten and Eibe 2014). For this study the highest F-Score corresponds to a threshold value t=0.98.

Selection of the matched entries

For the selection of the matched pairs the matching algorithm is run twice. In the first step, the companies and their subsidiaries in both datasets are matched only if they share the same country information. If the country information is not the same, the similarity value is set to 0. For companies without country information in one or both datasets, the country criterion is not used.

In the second step, the country criterion is excluded for all companies that are not assigned a corresponding entry in the first run. We did this only for the company headquarters, i.e. without subsidiaries, which had not been matched in the first run. The second step is to ensure that some potential correct matches are not missed as a result of including the country criterion in the first step. 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 can company divisions in different parts of the world be matched to the corresponding Scoreboard entry, i.e. Alcoa Deutschland is matched to Alcoa Inc., regardless of the country information.

Of the 2847 firms in the 2013 EU Industrial R&D Scoreboard (including subsidiaries), 2670 could be assigned a corresponding patent applicant in PATSTAT, i.e. 93 % of the firms listed in the *Scoreboard* are covered by the matching. In the first step of the matching, i.e. including the country criterion, 2432 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.

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