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Advanced Manufacturing Activities of Top R&D investors: Geographical and Technological Patterns

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Abstract

Advanced manufacturing technologies (AMTs) and other key enabling technologies (KETs) are expected to have a major impact on productivity, efficiency, profitability and employment in major industrial sectors worldwide. Thus, development of AMTs and KETs is considered essential if the European Union is to achieve the strategic goals set out in the European Commission's Employment, Growth and Investment priorities. Indeed, AMTs and KETs are among the top priorities identified as necessary to support the competitiveness of European industries in the context of the European flagship on industrial modernisation.

This study builds upon and extends results that were obtained in the context of the Advanced Manufacturing Technologies for Competitiveness AMTEC project, in which the technological profiles of the patent portfolios of the EU Industrial R&D Investment Scoreboard companies were constructed using patent-based analysis. In particular, their technological competences were investigated and it was found that European companies invest in KETs, and in particular in AMTs, as these technologies are considered to be vital for maintaining current competitiveness. However, other countries also invest heavily in AMTs and KETs.

It is therefore very important for the EU to define a strategy that aims to find a suitable position in the global value and innovation chains and that selectively augments existing capabilities. To this end, a methodology based on patent analysis was applied to assess the capacity of the world's top R&D investors in developing AMTs. Particular emphasis was placed on complex AMT patents that also pertain to at least one of the five KETs. These patents are considered important because they represent AMT applications used for the development of KETs in general or, conversely, they represent other KET applications that can be incorporated into AMT systems.

The main questions addressed by this study were (1) In which countries are the most important inventors of AMTs and applicants for AMT-related patents located? (2) Is it possible to analyse internationalisation patterns and knowledge flows between world regions and countries? and (3) Are there any special patterns and clusters between AMT-related technological fields and the five core KETs and, if so, which companies are responsible for the development of these technological applications?

Developing and patenting AMT-related technologies is particularly important for firms in the *Aerospace & defence, Industrials*, *Automobiles & parts* and *Electronics & electrical equipment* sectors. Moreover, the more specialised a sector is in developing AMT-related technologies, the less internationalised the AMT-related activities of the firms in the sector appear to be.

In general AMT-related R&D activities of European- and US-based firms are more internationalised than the activities of Japanese- and Asian-based companies. It was found that many Scoreboard firms based in the USA, Japan, Germany, France and the UK own and develop a large number of AMT-related patents. However, there are also many inventors of AMT-related technologies based in other countries, such as China, India, Canada, Italy, Belgium and Spain.

Finally, the ratio of complex AMT patents to the total number of AMT-related patents is close to 8%, the vast majority being patents that relate to micro- and nano-electronics, advanced materials or photonics. Companies that own these complex patents are often relatively small firms that are highly specialised in the development of AMT-related applications.

1. Introduction

Maintaining a globally competitive manufacturing sector is a priority not only for the EU, but also for all its main competitor regions, not least because the financial downturn of 2007/08 led to economic recession in many developed countries. As a result, new initiatives to boost the competitiveness of the manufacturing sector are under way around the world.[1] In the USA, the main focus has been on new technologies that rely increasingly on information, automation, software and networking, and are expected to play a key role in helping humanity to tackle societal grand challenges (IDEA Consult et al., 2013). In the same vein, the European Commission has placed special emphasis on a set of technologies labelled key enabling technologies (KETs) (European Commission Communication, 2009). In a 2014 communication, the European Commission (COM (2014) 14/2) highlighted the importance of stimulating investment in innovation and new technologies to maintain competitiveness and a strong industrial base for Europe's economic recovery. A 2016 European Commission communication (COM(2016) 180 final) identified the need to digitise European industry in order to reap the full benefits of the single market.[2] Such technologies are expected to simultaneously exploit and 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 simultaneously diminishing the adverse impact on the environment by reducing the volume of waste and pollution generated.

This study built and expanded on previous work (Neuhäusler et al., 2015) attempting to map the technological profiles of the world's top R&D investors, and to highlight the differences between European companies and their main global competitors. Using a methodology based on patent analysis, the technological profiles of the patent portfolios of the EU Industrial R&D Investment Scoreboard (hereafter the Scoreboard) companies were constructed in order to investigate their capacity to develop advanced manufacturing technologies (AMTs) and KETs. The study revealed that European companies do invest in KETs, and in particular in AMTs, because these technologies are considered to be vital for maintaining current technological competitive advantages. However, other countries are also investing heavily in KETs; therefore, it is essential that the EU to define a strategy that enables it to establish and consolidate an appropriate position in global value and innovation chains. This also involves selectively augmenting existing innovation capabilities.

In this context, the most compelling questions to be addressed are: (1) Which industrial sectors are most specialised in the development of AMT-related technologies? (2) Where are these technologies being developed? (3) Who are the final owners of the AMT-related technologies? and (4) How should the results in terms of policy implications be interpreted at Member State and EU levels. Answering these questions is rendered difficult by the lack of detailed company data. Most of the companies listed in the Scoreboard are multinational industrial groups operating in diverse markets and dealing

[1] https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf
[2] https://ec.europa.eu/digital-single-market/en/news/communication-digitising-european-industry-reaping-full-benefits-digital-single-market

with a diversified portfolio of technologies. Information disclosed in company reports and accounts is, in general, not sufficiently detailed to allow the location of different activities (research and development, production, etc.) to be identified, which hinders the possibility of mapping the geographical distribution of industrial activities and disentangling economic performance by world region or by country. Indeed, companies' decisions on where to locate their headquarters can be influenced by tax ruling systems; this is true even within Europe. In addition, preferential tax treatments based on output indicators such as patent boxes (rather than the usual input-based ones) can affect companies' decision on where to register their patents, encouraging them to file patents in countries without a corresponding flow of R&D (Alstadsæter et al., 2015).Despite all these caveats patent data are the most complete and accurate source of information and therefore in this report we rely on information about the inventor(s) location from patent documents to proxy the localisation of R&D activities.

Given the pervasiveness of KET-based components and products, and the competitive advantage of non-EU-based firms in the production of such technologies, as measured by the filing of KET-related patents (Gkotsis, 2015), another important question arises: (5) Which specific AMTs are used for the development of KETs with the most potential to have profound effects on key industrial sectors and, conversely, which KET-based components are crucial for the development of AMTs? This line of work includes comparative analyses of the competitiveness of the EU industry with respect to its main competitors, such as the USA, Japan and the emerging economies.

The data sources used in this study are the 2013 edition of the Scoreboard — collecting information on the world's top corporate R&D investors, which are responsible for almost 90% of the global R&D investment[3] — and the Worldwide Patent Statistical Database (PATSTAT).[4] Patents are the main output of technology-oriented R&D activities in technology-based sectors (Freeman, 1982; Grupp, 1998); patent documents contain a wealth of useful information about the invention, such as the technical fields to which the patent pertains and the addresses of the different actors in the innovation process (applicant and inventors). Patents filed by Scoreboard companies are related to KETs — and AMTs — using the technological definition proposed by the KETs Observatory.[5] This allows assignment of International Patent Classification (IPC) codes, as contained in the patent documents, to the different KETs identified by the European Commission.

The methodological approach and the data sources used in this study are presented in more detail in section 2. Section 3 presents data on the internationalisation of R&D activities targeting AMTs of the EU R&D Scoreboard companies. In subsection 3.4 a special focus is given to AMT-related patents that also relate to at least one of the remaining KETs. Finally, in section 4, the conclusions of this study are presented and the policy implications are discussed.

[3] For more information on the sample of companies included in the EU Industrial and R&D Investment Scoreboard, see http://iri.jrc.ec.europa.eu/scoreboard.html
[4] PATSTAT is the European Patent Office's Worldwide Patent Statistical Database, which contains data on about 70 million applications from more than 80 countries. See http://www.epo.org
[5] https://ec.europa.eu/growth/tools-databases/ketsobservatory

2. Methodology

The analysis presented in this report is based on the world top 2000 corporate R&D investors, as reported in the 2013 edition of the EU Industrial R&D Investment Scoreboard. The Scoreboard is part of the European Commission's monitoring activities to improve its understanding of trends in R&D investment by the private sector and the factors affecting it. Data for the Scoreboard are taken from the publicly available audited accounts of the companies, which in most cases do not include information about the location where R&D is actually performed. Thus, the whole R&D investment of Scoreboard companies is attributed to the country in which that company has its registered office. In the 2013 edition of the Scoreboard, companies' R&D rankings are based on information taken from their latest published accounts (see Appendix).

To analyse the technological outputs of top R&D investors' efforts, we retrieved the patents they filed during the 2010–12 period from PATSTAT. PATSTAT is a relational database that is updated twice a year and contains information about published patents from 83 patent authorities worldwide. All information provided on a patent application is included in the corresponding PATSTAT entry. The matching has been carried out on a by-country basis using a series of string matching algorithms; patent applicants were matched with Scoreboard companies, including their subsidiaries (Dernis et al., 2015).

Most of the analyses on the patenting activities of companies or countries are based on one specific Intellectual Property Office (IPO), generally the USPTO (United States Patent and Trademark Office) or the EPO (European Patent Office). However, companies tend to file the majority of their patent applications in the IPO of their home country, and this country bias in patent statistics is particularly pronounced in the case of Japanese and Chinese firms (Dernis et al., 2015). In order to reduce the country bias, this study considers patents that have been filed at the EPO or the USPTO. In order to control for the multiple filing of the same invention at both IPOs, different patent applications have been matched through INPADOC (International Patent Documentation) families to avoid double counting.[6]

Information on the location of inventors and owners, as reported in patent documents, is used as a proxy for the localisation of the R&D activities of Scoreboard companies. Innovation activities are defined as international when the location of the inventor is different from the location of the Scoreboard company that is the legal owner of the intellectual property rights. In the cases of multi-inventors from multiple countries, fractional counts of the same patent family between the different countries are applied.

The IPC is a hierarchical classification system used primarily to classify and search patent documents according to the technical fields they pertain to. It contains about 70 000 entries identified by classification symbols (IPC codes) that can be allotted to patent documents. These different classification codes are organised in a tree-like, hierarchical structure. The IPC is updated annually and revised every three years to capture technological changes more effectively (WIPO, 2006). For consistency with existing figures on patents relating to KETs and AMT, for the purpose of this report we use the definition of KETs that has been developed by the KETs Observatory, in which AMT is defined as a subfield of KETs (IDEA Consult et al., 2013) (see Appendix).

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[6] For a definition of INPADOC family, see http://www.epo.org/searching/essentials/patent-families/inpadoc.html

A patent document may contain different IPC codes and therefore refer to different technologies. In this work, we focus on patent families pertaining specifically to AMTs or KETs in general. We define complex patents as those related both to AMTs and to another KET, and assume that these patents can represent AMT applications used for the development of KETs or, conversely, they can represent other KET applications that can be incorporated into AMT systems. Finally, when interpreting the results of this study, it should be noted that the results of purely patent-based analysis cannot exhaustively represent the relative importance of firms in the development of AMTs or KETs, particularly when considering those that are crucial for the development of other KETs or AMTs. A complete picture could be drawn by complementing the results with different types of studies targeting the analysis of specific technological solutions.

3. AMT-related patenting activities of Scoreboard companies

The analysis of the R&D activities related to AMTs, their connection with other KETs and the geographical configuration of AMT-inventive activities is based on the patent applications filed by the Scoreboard companies at the EPO or USPTO between 1 January 2010 and 31 December 2012. Of the top 2 000 R&D investors, 1752 filed patents at these two IPOs during this period. The total number of patent families filed during the same period was 510970.

The proportion of all patents that belong to AMT-related families is close to 5% (25631 patents from AMT-related families were identified), and these patents were filed by 1102 companies, although 82% of all patents in AMT-related families are owned by just 188 companies.

3.1 AMT development across industrial sectors

The starting point for the analysis was the relative importance of AMT-related patents for different industrial sectors. In order to investigate the contribution of different industries to the development of AMTs, firm-level patent information was aggregated in accordance with the Industry Classification Benchmark (ICB) four-digit level. Table 1 reports the industrial sectors with the highest number of patent families related to the development of AMTs.

The production of new AMTs appears to be concentrated in a narrow group of industrial sectors. In particular, Table 1 shows that almost 80% of all AMT-related patent families in the sample have been developed by companies operating in only five industry sectors: *Industrials*, *Electronics & electrical equipment, ICT producers*, *Automobiles & parts* and *Aerospace & defence*.

However, the propensity to patent (i.e. the number of patents obtained per unit of R&D investment; Scherer, 1983) varies greatly across industries. In particular, companies operating in ICT-related industries have a much higher average propensity to patent than companies in other industries such as the automobile industry (Dernis et al., 2015). As a result, companies operating in these industries tend to hold larger patent portfolios than those operating in other sectors; comparisons of numbers across sectors are partly driven by these underlying differences between industries.

Table 1 - Proportion of AMT-related patents by Industrial Sector

Sector (Number of AMT Patents)	Ratio of AMT patents
Industrials (5540.8)	21.6%
Electronic & Electrical Equipment (5095.7)	19.9%
ICT producers (4280.2)	16.7%
Automobiles & parts (3559.5)	13.9%
Aerospace & defence (1926.2)	7.5%

Source: *Authors' own calculations on EPO and USPTO patent applications. ICT, information and communication technology.*

The importance of AMTs for technological competitiveness is likely to be sector specific. Therefore, an alternative way to capture its importance is to consider the proportion of AMT-related patent families with respect to the overall patent portfolio of the industry. Table 2 reports the five industries with the highest proportions of AMT-related patent families.

Table 2 - Relative importance of AMT-related patents in the patent portfolio of companies within specific sectors

Sector (Number of AMT Patents)	AMT patents	Total Patents	AMT /Total
Aerospace & defence	1926.2	15004.5	12.8%
Alternative energy	72.0	694.3	10.4%
Industrials	5540.8	57421.5	9.6%
Automobiles & parts	3559.5	41932.6	8.5%
Traditional energy	202.5	2408.6	8.4%

Source: *Authors' own calculations on EPO and USPTO patent applications.*

Among the sectors with the highest number of AMT-related patent families discussed above, the ratio of AMT-related patents to total patents is highest in the *Aerospace & defence, Industrials* and *Automobiles & parts* sectors. The proportion of AMT-related patents is also high in the energy industries, although the total number of patents in companies' portfolios tends to be much lower than in other industries. In the *Electronics & electrical equipment* sector, not reported in Table 2, the proportion of AMT-related patent families is higher than the sample mean (5.7% vs. 5%).

Based on the results of Table 1 and Table 2, in section 3.3 we will focus our analysis on the internationalisation of AMT-related innovative activities, considering companies

operating in the *Industrials*, *Electronics & electrical equipment, Automobiles & parts* and *Aerospace & defence* sectors. This allows us a sufficiently large number of patent families to guarantee robustness of the results and to consider industries in which AMTs represent an important part of the overall technological development. Indeed, companies operating in these four sectors were responsible for almost 63% of the AMT-related filings between 2010 and 2012. At the same time they showed a high degree of specialisation in AMTs. [7]

Before moving to the analysis of the internationalisation patterns of AMT-related innovative activities, we will first look at complex patents.

3.2 Complex patents (AMTs and KETs)

Advanced manufacturing technologies are expected to revolutionise existing industrial processes. Moreover, these technologies can be also linked to the development of the other five KETs, namely nanotechnology, industrial biotechnology, micro- and nano-electronics, photonics and advanced materials. In many cases KET-based components are also vital for the development of AMTs. This section focuses on patent families combining IPC codes that correspond to AMTs with IPC codes that correspond to at least one of the five KETs. The idea underlying this exercise is that these patents could represent AMT systems used for the development of KETs or they could represent KET components that are vital for the development of AMTs. Different KETs converge in these patents families, which may represent particularly promising technological solutions. However, it is worth considering that the approach based on the assumption of co-occurrence of KET-related codes in the same patent document may not capture certain aspects of the technological development process. On the one hand, it may be the case that not all of the patents identified represent uses of KETs for the development of AMT applications (and vice versa). On the other hand, this approach might fail to identify some patents (and techniques) that are important for the development of KETs and AMT-related applications.

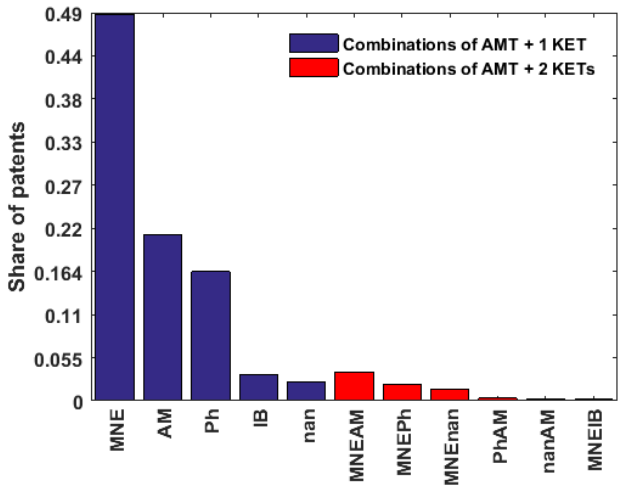
In total, 1834 patent families combining AMT-related IPC codes with IPC codes related to one or two of the core five KETs were identified. The proportion of AMT-related patent families that also relate to at least one of the KETs was 7.8%, making this a not insignificant phenomenon. Figure 1 shows the proportion of patents combining AMT-related IPC codes with other KETs; combinations involving two other KETs are plotted in red.

About half of complex patent families (897) combine micro- and nano-electronics with AMTs. Combinations of AMTs with advanced materials or photonics are the next two most frequent pairings, together representing about 37% of the total complex patent families. Combinations of AMTs with nanotechnology (45 patent families) and industrial biotechnology (60 patent families) are much less common. With 148 patent families, combinations of AMTs with two or more KET-related IPC codes represent 8.1% of the total complex patent families. The vast majority of these patent families (130) include

[7] Specialisation in this context refers to the ratio of patents related to a specific field over the total number of patents.

combinations of AMTs and micro- and nano-electronics with either advanced materials, photonics or nanotechnology.

Figure 1 - Distribution of combinations of AMT and other KETs



Source: *Authors' own calculations on EPO and USPTO patent applications.*

Which are the Scoreboard companies developing these complex technologies? Table 3 reports the top 10 patenting companies for each of the combinations involving AMTs and another KET. The table also reports the number of complex patent families, their proportion of AMT-related patent families and the total number of patent families owned by the company. For each company, the proportion of AMT-related patents over the total patent portfolio was calculated and compared with the industry average. Firms with proportions of AMT-related patent families that are higher than the industry average (i.e. that are relatively specialised in AMT production) are reported in bold blue, those within 5% of the average are reported in normal blue, while those lower than the industry average are reported in red.

Many of the companies present in these top 10 lists are relatively small in terms of the size of their overall patent portfolios. These companies appear to be highly specialised in the development of AMTs; in most cases their level of specialisation is higher than the average specialisation of the industry in which they operate. In addition, the proportion of complex patent with respect to AMT patents is generally higher than the sample average (7.8%).

Table 4 reports the top 10 companies that develop patent families combining AMT-related IPCs with two or more KETs. Only combinations of AMTs with micro-electronics and nano-electronics-related IPC codes that also relate to advanced materials, photonics or nanotechnology are shown; these represent the vast majority (87%) of the total complex patents involving three or more KETs. Many of the companies shown in Table 4 do not own large patent portfolios.

Table 3 - Top 10 companies owing patents that combine AMT with another KET

Company (Industry)	AMT + MNE	Complex % on AMT	Patent Families
IBM (ICT services)	34	10%	15938
APPLIED MATERIALS (ICT producers)	30	24%	1421
TOKYO ELECTRON (ICT producers)	27	27%	1328
RENESAS (Electronic & Electrical eq)	26	21%	2201
TAIWAN SEMICONDUCTOR (ICT producers)	25	22%	3261
TOSHIBA (Industrials)	24	8%	9550
HITACHI (Electronic & Electrical eq)	24	8%	6629
HAMAMATSU PHOTONICS (Electronics & Electrical eq)	23	77%	273
SEIKO EPSON (ICT producers)	22	10%	4505
INFINEON TECHNOLOGIES (ICT producers)	22	20%	1473

Company (Industry)	AMT + AM	Complex % on AMT	Patent Families
NIPPON STEEL (Industrials)	29	35%	812
KOBE STEEL (Industrials)	23	27%	573
GENERAL ELECTRIC (Industrials)	20	2%	9012
UNITED TECHNOLOGIES (Aerospace & defence)	16	3%	3219
APPLIED MATERIALS (ICT producers)	10	8%	1421
SIEMENS (Electronic & electrical eq)	10	1%	6712
DOW CHEMICAL (Chemicals)	7	3%	4119
FUJIFILM (Electronic & electrical eq)	7	9%	5165
SUMITOMO ELECTRIC (Electronic & electrical eq)	7	13%	1717
HITACHI (Electronic & electrical eq)	6	2%	6629

Company (Industry)	AMT + Photonic	Complex % on AMT	Patent Families
PHILIPS (Industrials)	19	15%	3472
QUALCOMM (ICT producers)	14	9%	5998
APPLE (ICT producers)	7	4%	3930
KOITO MANUFACTURING (Automobile & parts)	6	60%	304
SIEMENS (Electronic & electrical eq)	6	1%	6712
ACUITY BRANDS (Others)	5	45%	68
CANON (ICT producers)	5	2%	10970
GENERAL ELECTRIC (Industrial)	5	0.5%	9012
TAIWAN SEMICONDUCTOR (ICT producers)	5	4%	3261
SAMSUNG DISPLAY (Electronic & electrical eq)	5	10%	2724

Company (Industry)	AMT + Ind Biotec	Complex % on AMT	Patent Families
ABBOTT LABORATORIES (Pharmaceuticals & Biotechnology)	4	5%	1278
LIFE TECHNOLOGIES (Pharmaceuticals & Biotechnology)	4	22%	459
PHILIPS (Industrials)	4	3%	3472
EPPENDORF (Health)	3	30%	74
GENERAL ELECTRIC (Industrials)	3	0.3%	9012
BIOMERIEUX (Pharmaceuticals & Biotechnology)	2	50%	124
DOW CHEMICAL (Chemicals)	2	1%	4119
JOHNSON & JOHNSON (Pharmaceuticals & Biotechnology)	2	5%	2072
LUMINEX (Pharmaceuticals & Biotechnology)	2	67%	25
QIAGEN (Pharmaceuticals & Biotechnology)	2	67%	102

Company (Industry)	AMT + Nano	Complex % on AMT	Patent Families
AREVA (Traditional energy)	6	4%	1608
IBM (ICT services)	4	1%	15938
HON HAI PRECISION INDUSTRY (Electronic & elctrical eq)	3	1%	9584
FAIRCHILD SEMICONDUCTOR (ICT producers)	2	8%	207
FREESCALE (ICT producers)	2	3%	1008
QUALCOMM (ICT producers)	2	1%	5998
ROBERT BOSCH (Autmobile & parts)	2	0.4%	5044
SAMSUNG ELECTRO-MECHANICS (Electronic & elctrical eq)	2	2%	1944
XEROX (ICT producers)	2	2%	3026
3M (Inductrials)	1	3%	1597

Source: *Authors' own calculations on EPO and USPTO patent applications.*
Note: *The width of coloured bar is proportional to the column value within each panel.*

These companies appeared to be highly specialised in developing AMT-related patents. Indeed, in the majority of cases, the proportion of AMT-related patent families in their patent portfolio is higher than the sector average. In addition, many of the companies reported in Table 4 have very high proportions of complex patent families with respect to AMT-related patents. Overall, the results seem to suggest a positive relationship between a company's technological specialisation and its capacity to develop complex KETs. A particularly interesting case is that of US-based company Applied Materials; this company filed 1421 patent families during the period under consideration, is relatively specialised in the development of AMTs and appears among the top 10 in four out of the eight lists of complex patent family owners.

Table 4 - Top 10 companies owning patents that combine AMT with two or more KETs

Company (Industry)	AMT MNE AM	% on AMT	Patent Families	Company (Industry)	AMT MNE Photonic	% on AMT	Patent Families	Company (Industry)	AMT MNE Nano	% on AMT	Patent Families
LAM RESEARCH (ICT producers)	12	26%	449	INTERSIL (ICT producers)	3	4%	243	ELMOS SEMICONDUCTOR (ICT producers)	4	36%	35
TOKYO ELECTRON (ICT producers)	11	11%	1328	CREE (ICT producers)	2	12%	347	AREVA (Traditional energy)	4	2%	1608
APPLIED MATERIALS (ICT producers)	7	6%	1421	PHILIPS (Industrials)	2	2%	3472	SEIKO EPSON (ICT producers)	3	1%	4505
PANASONIC (Other)	4	1%	9460	QUALCOMM (ICT producers)	2	1%	5998	INFINEON TECHNOLOGIES (ICT producers)	2	2%	1473
NIPPON STEEL (Industrials)	3	4%	812	SAMSUNG DISPLAY (Electronic & electrical eq)	2	4%	2724	ROBERT BOSCH (Automobiles & parts)	2	0.4%	5044
FUJITSU (ICT services)	2	1%	8460	SHARP (Electronic & electrical eq)	2	5%	3828	FREESCALE (ICT producers)	2	2%	1008
JX (Low)	2	22%	221	APPLIED MATERIALS (ICT producers)	1	1%	1421	BOEING (Aerospace & defence)	1	0.3%	1899
ASAHI GLASS (Industrials)	1	6%	809	AREVA (Traditional energy)	1	1%	1608	DAI NIPPON PRINTING (Services)	1	11%	356
BE AEROSPACE (Aerospace & defence)	1	3%	1870	ASM INTERNATIONAL (ICT producers)	1	17%	118	IBM (ICT services)	1	0.3%	15938
BROOKS AUTOMATION (Industrials)	1	6%	56	AVAGO TECHNOLOGIES (ICT producers)	1	3%	291	LOCKHEED MARTIN (Aerospace & defence)	1	2%	737

Source: *Authors' own calculations on EPO and USPTO patent applications.*
Note: *The width of coloured bar is proportional to the column value within each panel.*

Finally, a consideration about the potential of AMT-related patents. The scope of the patent, that is the number of technological fields (IPC codes) to which the patent pertains, is often related to the technological and economic value of patents; moreover, patent portfolios with a higher average scope are associated with higher market valuations of the owning company (Lerner, 1994). The average scope, calculated at the IPC8 level,[8] of all of the patent families filed by the Scoreboard companies during the period under study, is 2.65. The average scope of the AMT-related patents in the sample is much higher, at 3.96. AMT-related patents have a higher technological breadth than the other patents in the sample, which suggests that they might also be particularly valuable from the technological and economic points of view. However, further analysis would be needed to confirm this.

[8] The International Patent Classification is a hierarchical classification scheme organised in eight main sections (IPC1) and an increasing number of classes (IPC3), subclasses (IPC4) and groups (IPC8).

3.3 The internationalisation of AMT-related activities

The focus of both this section and the next is the international dimension of AMT-related innovative activities. As previously discussed, these sections will focus on the behaviour of companies operating in the *Industrials, Electronics & electrical equipment*, *Automobiles & parts* and *Aerospace & defence* sectors. This allows us to have a sufficiently large number of patent families for our study, and to analyse industries for which AMTs represent an important part of the overall technological development.

Table 5 reports the distribution of AMT-related patent families across different world regions based on information retrieved from patent filings by companies in the *Industrials* sector. Firms in the *Industrials* sector filed 5 541 AMT-related patent families between 2010 and 2012. The proportion of inventors residing in the same world region as the company applying for the patent family was 79%; the remaining 21% of patent applications were developed internationally.

The proportion of AMT-related patent families applied for by EU- and US-based companies from inventors residing in the same region was quite similar, 80.6% and 79.3% respectively. However, while 10.8% of US-owned patents (268) were developed by inventors residing in the EU, 14% of the EU-owned patent families were developed by inventors located in the USA. Overall, US companies filed more AMT-related patent families than EU companies during the period considered in this report. This is reflected in the fact that, although the proportion of EU patents developed in the USA was higher, when considering total numbers, the number of US-owned patent families developed in the EU was higher (268 vs. 161). AMT-related R&D activities of Japanese-based companies appear to be quite concentrated; 93% of filings came from inventors residing in Japan.

Table 5 - International location of AMT-related patenting activities: *Industrials*

AMT patents - Industrials

Applicant Region (Number of patent families)	Inventor Region			
	EU	*Japan*	*USA*	*RoW*
EU (1152)	80.6%	0.4%	14.0%	5.0%
Japan (1305)	1.8%	93.0%	4.3%	0.9%
USA (2681)	10.8%	0.2%	79.3%	9.7%
RoW (403)	50.2%	0.3%	16.7%	32.7%

Source: *Authors' own calculations on EPO and USPTO patent applications. RoW, rest of the world.*

Table 6 - International location of AMT-related patenting activities: *Electronics & electrical equipment*

AMT patents Electronic & Electrical Equipment

Applicant Region (Number of patent families)	Inventor Region				
	Asian Tigers	*EU*	*Japan*	*RoW*	*USA*
Asian Tigers (1299)	70.3%	0.3%	0.4%	26.8%	2.2%
EU (1272)	0.3%	70.5%	0.3%	5.3%	23.6%
Japan (1592)	0.4%	3.2%	92.0%	0.5%	3.9%
RoW (187)	6.9%	53.5%	0.8%	16.0%	22.8%
USA (746)	0.5%	11.4%	0.0%	6.6%	81.5%

Source: *Authors' own calculations on EPO and USPTO patent applications.*
Asian Tigers: *South Korea, Taiwan, Hong Kong and Singapore.*
RoW, rest of the world.

Firms in the *Electronics & electrical equipment* sector filed 5 096 patent families during the period considered. The ratio of AMT-related families filed by inventors that were located in the same region as the applicant is 76.7% (slightly lower than companies in the *Industrials* sector). Most of the patent families come from Japanese-based companies, followed closely by firms from the Asian Tiger economies (Singapore, South Korea, Taiwan and Hong Kong) and from the EU. Table 6 shows that AMT-related R&D activities of firms based in the EU or the Asian Tigers countries are more internationalised than those of their US- and Japanese-based counterparts.

It is also interesting to note that almost one in four (23.6%) of the EU-owned patent families come from US-based inventors, while 11.4% of US-owned patent families come from EU inventors. Japanese firms are the least internationalised, with 92% of their total number of AMT-related patents deriving from inventors located in Japan; US-based firms followed closely with 81.5%.

Table 7 presents the results obtained from the analysis of companies operating in the *Automobiles & parts* sector. Companies in this sector filed 3 560 AMT-related patent families between 2010 and 2012. The proportion of patents with inventors residing in a different region of the world from the owner is almost 20%. European and Japanese firms hold the majority of AMT-related patent filings; however, their patenting activities across the world are slightly different. EU firms are more internationalised, with 17.2% of their patent filings coming from US-based inventors. The corresponding figure for firms based in Japan is 13.4%. Japanese companies operating in the *Automobiles & parts* industry appear to be more internationalised than their counterparts operating in the *Industrials* and *Electronics & electrical equipment* sectors. Finally, 24.5% of the total number of US-owned patent families that relate to AMT have EU-based inventors, the

opposite to the findings for the *Industrials* and *Electronics & electrical equipment* industries.

Table 7 - International location of AMT-related patenting activities: *Automobiles & parts*

AMT patents - Automobiles & Parts				
Applicant Region (Number of patent families)	Inventor Region			
	EU	*USA*	*Japan*	*RoW*
EU (1333)	79.3%	17.2%	1.0%	2.2%
USA (744)	24.5%	70.1%	0.4%	5.0%
Japan (1321)	2.0%	13.4%	83.6%	1.0%
RoW (162)	6.7%	0.7%	0.0%	92.6%

Source: *Authors' own calculations on EPO USPTO patent applications. RoW, rest of the world.*

Companies operating in the *Aerospace & defence* sector appear by far the least internationalised of those considered in the study. During the three-year period considered, companies in this sector accounted for 1926 patent families. The vast majority of these patent families (almost 99% of the total) came from EU- and US-based companies; these two regions seemed to retain an edge in the technological development of this sector. Moreover, AMT-related patenting activities are quite geographically concentrated; this is probably because of the strategic importance of this sector. Of the patent families owned by US-based companies, 91.3% were invented by US-based invertors. Likewise, 92.6% of EU-owned AMT-related patent were invented within the EU. A very small number of EU-owned patent families (approximately 54) were developed in the USA. Similarly only about 48 US-owned patent families were invented by EU-based inventors.

It can be observed that, although the proportion of AMT-related patent families filed by companies operating in the four industrial sectors considered in the analysis was higher than the average (close to 5%), the internationalisation of their AMT-related patenting activities varied greatly. In particular, *Aerospace & defence* companies are the least internationalised; these companies are also those with the highest proportion of AMT-related patent families in their overall patent portfolios (Table 6). AMTs are likely to be key to guaranteeing a competitive position in this sector and, given their strategic importance, they tend to be developed locally. On the other hand, firms in the *Electronics & electrical equipment* sector, with 5.7% of their total patent families related to AMTs, are the most internationalised group of companies analysed. Companies from the other two sectors, *Industrials* and *Automobiles & parts*, show similar levels of internationalisation, between the two extremes.

Table 8 - International location of AMT-related patenting activities: Aerospace & defence

AMT patents - Aerospace & Defence			
Applicant Region (Number of patent families)	Inventor Region		
	EU	*USA*	*RoW*
EU (894)	92.6%	6.0%	1.0%
USA (1008)	4.8%	91.3%	3.9%
RoW (24)	10.4%	10.4%	79.1%

Source: *Authors' own calculations on EPO USPTO patent applications. RoW, rest of world.*

3.4 A closer look at the AMT international innovation network

In this section we attempt to assess the contribution of different countries to the development of AMT. In particular, we look at the linkages between the location of patent owners and inventors. In doing so, we disentangle the geographical ownership structure of AMTs and the links and collaboration networks between countries around the world.

To draw the AMT international innovation networks, all the AMT-related patents from Scoreboard companies were considered. Applicant and inventor information from patent documents was aggregated at the country level and individual countries were used as nodes in the network.[9] Links between nodes (countries) correspond to collaboration between inventors and applicants from different countries for the development of AMT-related patents. To facilitate the visualisation of knowledge flows between different countries, the links between nodes — the edges — were directed from the inventor to the applicant country. The number of incoming links (incoming degree) to a country is an indication of knowledge flowing from inventors residing abroad to owners based in that country. The number of outgoing links (outgoing degree) from one country relates to knowledge flowing from this country abroad.

The world network of 'owner' and 'inventor' countries of AMT-related patent filings is shown in Figure 2. In the figure we condense information surrounding the AMT international innovation network, in particular:

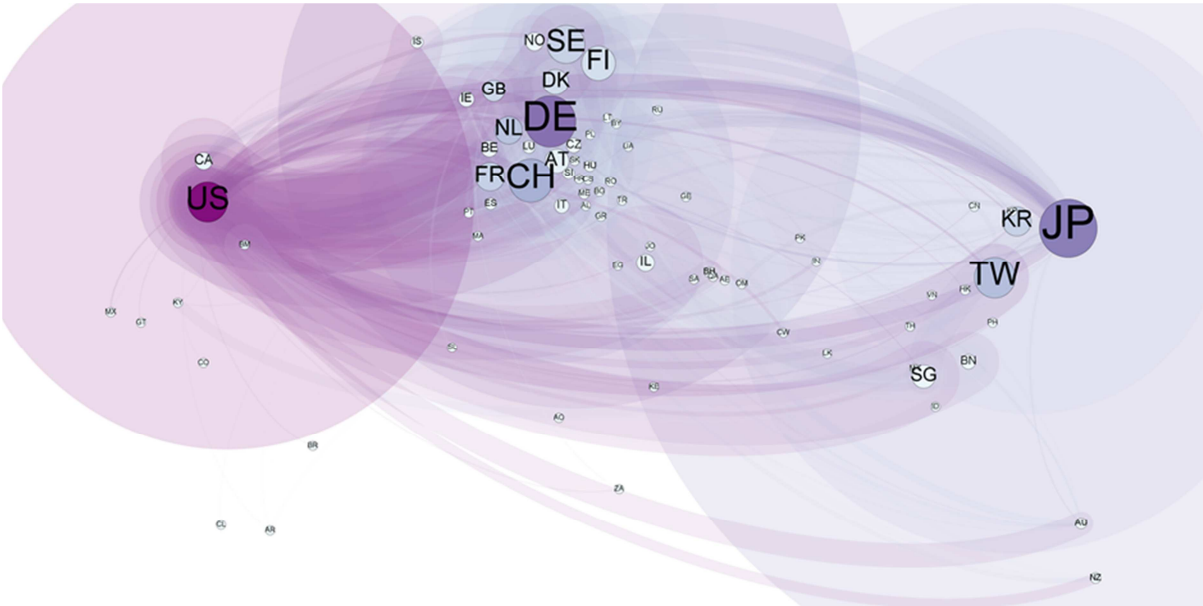
1) The colour of the nodes varies between purple for the country with the highest incoming weighted degree (most important in term of patent applications) and

[9] In network analysis, the structure of a network is characterised in terms of nodes (the entities within the network) and ties or edges (relationships or interactions) that connect them.

pink for the country with the lowest incoming weighted degree (the least important in terms of patent applications);

2) The size of the nodes depends on the outgoing weighted degree (the higher the outgoing degree, the larger the node), which represents the number of connections between a country inventors with applicants from abroad.

Figure 2 - International patent network of Scoreboard companies based on AMT-related patent filings between 2010 and 2012



Source: *Authors' own calculations on EPO and USPTO patent applications.*

In the figure, we report weighted degrees, which is a measure of the number of different countries that are home to the inventors and applicants of AMT-related patents. The relative importance of a link between two countries, which is represented by an edge in the graph and corresponds to collaborations between applicants and inventors residing in these two countries, is assessed by the number of patents that have been co-developed by applicants and inventors from the two countries. Thus, these metrics are not only an indication of internationalisation, but also assess the relative importance of collaborations by taking into account the number of developed patents.

US-based companies own a large number of AMT-related patent families that were developed in collaboration with inventors from many different countries outside the USA. At the same time, the USA is also an important inventor country: US inventors have developed AMT-related patents with applicants from many other countries. In terms of ownership of AMT-related technologies, US-based companies are closely followed by companies based in Japan, Germany and France. Switzerland, the UK, South Korea, Taiwan and the Netherlands are also countries where companies owning AMT-related patents are located. All of these countries are also important when considering the location of the inventors developing AMT-related technologies. US-based companies have established close links and are highly interconnected with Japanese, European, South Korean and Taiwanese companies. European companies are also highly interconnected both with other EU companies and with US-based companies. Finally

Japanese, South Korean, Taiwanese and Chinese companies form another important cluster for the development of AMT-related patents.

We next focus on the internationalisation of the AMT-related patenting activities of companies from the *Automobiles & parts* and *Aerospace & defence* sectors: industries that are particularly AMT intensive and where the EU has a comparative advantage over most of its competitors elsewhere. Table 9 lists the top 10 AMT-related patent owners in the *Automobiles & parts* sector. Companies are ranked in accordance with the number of AMT-related patent families owned and the three most important countries, in terms of residence of inventors, are reported. We further distinguish between companies whose proportion of AMT-related patents in their total portfolios is higher than the sector average (deep blue) and those for which this proportion is lower than the sector average (light blue, italic). Most of the top 10 AMT-related patent applicant companies operating in the *Automobiles & parts* sector tend to develop their technologies 'in house'.

Indeed, in most cases, the country in which a company's headquarters is located is also where the majority of technologies are developed. However, the need to utilise the skills of international inventors varies greatly across companies. In contrast to Hyundai Motor, which develops almost all of its AMT-related patents in South Korea, Continental and Volkswagen are among the most 'internationalised' companies. Fiat (which acquired the Chrysler F platform) and Delphi Automotive (which began as the parts arm of GM) represent exceptions in this group, with the majority of their AMT-related technologies developed abroad.

Table 9 — AMT-related international R&D activities of the world's top 10 firms by number of AMT-related filings of the *Automobiles & parts sector*

Automobile & Parts								
Company	R&D 2012 (€ mil.)	Patent Families	AMT	HQ Country	AMT - Inventor Countries			
					US	DE	IT	Other
GENERAL MOTORS	5,584	4608	508	US	76.1%	13.1%	4.4%	6.4%
					DE	US	JP	
ROBERT BOSCH	4,924	5044	496	DE	76.9%	12.8%	2.1%	8.2%
					JP	US	GB	
DENSO	2,938	2800	307	JP	96.9%	2.4%	0.3%	0.4%
					JP	US	DE	
HONDA MOTOR	4,906	3096	298	JP	73.4%	22.9%	2.5%	1.2%
					JP	US	CA	
TOYOTA MOTOR	7,071	4312	296	JP	74.7%	21.9%	3.0%	0.4%
					DE	SE	FR	
VOLKSWAGEN	9,515	1780	144	DE	66.4%	27.2%	2.1%	4.4%
					DE	US	FR	
CONTINENTAL	1,827	1084	130	DE	60.9%	24.4%	8.3%	6.4%
					KR	DE		
HYUNDAI MOTOR	934	1999	99	KR	99.5%	0.5%		
					US	IT	DE	
FIAT	3,295	448	86	IT	52.0%	37.4%	6.4%	4.1%
					US	FR	DE	
DELPHI	910	524	67	GB	67.7%	17.7%	6.7%	8.0%

Source: *Authors' own calculations on EPO and USPTO patent applications.*

The top 10 AMT-related patent owners in the *Aerospace & defence* sector are listed in Table 10. As before, companies are ranked by number of AMT-related patent families and the three most important inventor countries are reported. Almost all companies in the list develop the vast majority of their AMT-related patents in the country in which the headquarters is located. The proportion of AMT-related patents developed 'in-house' in the *Aerospace & defence* sector is generally much higher than for companies operating in the *Automobiles & parts* sector. An important exception is EADS, whose headquarters is located in the Netherlands, but whose main R&D activities take place in other European countries (EADS was formed by the merger of different European aerospace companies and currently has the statute of European company). The next most internationalised firm of in the sector, in terms of location of AMT-related R&D activities, is BAE systems, with almost 40% of its AMT-related patent families developed outside the UK and almost one-quarter of these in the USA.

Table 10 - International R&D activities of the world's top 10 firms by number of AMT-related filings of the *Aerospace & defence* sector

Company	R&D 2012 (€ mil.)	Patent Families	AMT	HQ Country	AMT - Inventor Country			
UNITED TECHNOLOGIES	1797	3219	482	US	US 89.2%	CA 6.0%	GB 1.3%	Other 3.5%
EADS	3630	2438	324	NL	FR 48.3%	DE 32.9%	GB 9.0%	9.8%
BOEING	2253	1899	300	US	US 94.1%	ES 3.5%	DE 1.3%	1.1%
ROLLS-ROYCE	750	924	167	GB	GB 78.7%	DE 11.1%	US 6.3%	3.9%
SAFRAN	1109	1145	155	FR	FR 90.3%	BE 5.2%	US 3.5%	1.0%
MTU AERO ENGINES	161	241	62	DE	DE 98.4%	CH 0.8%	PL 0.8%	
THALES	700	745	61	FR	FR 96.7%	BE 1.6%	DE 0.8%	0.8%
BAE SYSTEMS	189	591	57	GB	GB 62.8%	US 24.3%	FR 5.3%	7.5%
LOCKHEED MARTIN	467	737	54	US	US 99.1%	IN 0.9%		
TEXTRON	443	285	46	US	US 89.1%	DE 8.7%	CA 2.2%	

Source: *Authors' own calculations on EPO and USPTO patent applications.*

Similar figures for 'owner' and 'inventor' countries of AMT-related patent filings can be compiled for the *Industrials* and *Electronics & electrical equipment* sectors. Based on the incoming degree criterion, the most important 'applicant' countries, in terms of firms from the *Industrials* sector owning AMT-related patent families that were developed by domestic and international inventors, are the USA, Switzerland, Germany and Japan. These countries, along with Italy and France, are also important inventors of AMT-related patents, as shown by the outgoing degree criterion.

Finally, the USA, Germany, France, Japan, the Netherlands and Switzerland are important applicant countries in terms of 'owners' of AMT-related technologies for the

Electronics & electrical equipment sector. They are also important 'inventor' countries, along with China and the UK.

4. Conclusion

In this report, empirical evidence about the internationalisation of AMT-related R&D activities of Scoreboard companies operating in sectors that are highly specialised in the development of AMT-related patents is presented. Patent data from applications filed at the EPO and the USPTO were linked to Scoreboard companies and information from patent documents on the location of the applicant and the inventors was used for this analysis. The focus on firm-level data allowed analysis of where most of the AMT-related R&D activities take place and what is the ownership structure of the resulting AMT-related technologies. Given that KET components are integrated into AMT-based systems, and that, among other applications, AMT-related technologies are being used for the development of KET-based products, we focused on complex AMT patents, i.e. those also related to other KETs.

The starting point for the analysis was to look at the sectors in which the development of AMT-related technologies is crucial. Based on the proportion of total patents that relate to AMTs, and on the specialisation of companies in different sectors, it was found that developing and patenting AMT-related technologies is of crucial importance for firms in the *Aerospace & defence, Industrials*, *Automobiles & parts* and the *Electronics & electrical equipment* sectors, which together own almost 80% of the AMT-related patent families that were filed during the period under study.

The more specialised in developing AMT patents a sector is, the less internationalised the AMT-related activities of the firms in this sector appear to be. The most concentrated AMT-related R&D activities are performed by firms in the *Aerospace & defence* sector, with over 90% of their AMT-related patents being developed in the world region where the applicant is based. These firms are highly specialised in developing AMT-related technologies, with 12.8% of their total patent filings classified as AMTs, compared with global average of close to 5%. Firms in the *Aerospace & defence* sector were responsible for 7.5% of the total AMT-related filings during the period under study; most of these were developed in the USA, the UK, Germany and France. Firms in the *Industrials* and in the *Automobiles & parts* sectors are also highly specialised in the development of AMT-related technologies. They are followed by companies in the *Electronics & electrical equipment* sector, which file almost 5.7% of their patent families in AMT-related technological fields.

In general, AMT-related R&D activities of European- and US-based firms are more internationalised than the activities of Japanese- and Asian-based firms. In most cases the proportion of AMT-related patents that are developed in the same region where the applicant is based is 70–80%, a notable exception being Japanese-based companies, which show highly concentrated AMT-related R&D activities. Analysis of the ownership structure of AMT-related patents and possible knowledge flows between different countries was undertaken by exploiting the information about the location of inventors and applicants in patent filings. It was found that in some countries, such as the USA, Japan, Germany, France and the UK, many Scoreboard firms own and develop a large number of AMT-related patents. However, large numbers of inventors of AMT-related

technologies are also based in other countries, such as China, India, Canada, Italy, Belgium and Spain.

We also focused on AMT-related patents that relate to at least one or more of the KETs; this was an attempt to assess the capability of Scoreboard firms to develop complex patents that can be assumed to link to AMT applications for the development of KETs, or to KET applications that can be incorporated into AMT systems. However, it should be borne in mind that the results of this type of analysis are by no means exhaustive and the relative importance of firms in the development of AMTs or KETs that are crucial for the development of other KET- or AMT-related applications should be complemented by different types of studies. It is found that approximately 8% of the AMT-related patents fall into this category of complex patents, the vast majority being patents which relate to micro- and nano-electronics, advanced materials and photonics. It is found that many of the firms that are mainly responsible for the development of these technologies are relatively small in terms of the total number of patent families in their portfolios but are highly specialised in the development of AMT-related patents.

References

Alstadsæter A, Barrios S, Nicodème G, Skonieczna AM, Vezzani A, 'Patent Boxes Design, Patents Location and Local R&D'. Taxation Papers, N.57, 2015.

Dernis H, Dosso M, Hervás F, Millot V, Squicciarini M, Vezzani A, 'World Corporate Top R&D Investors: Innovation and IP bundles'. A JRC and OECD common report. Luxembourg: Publications Office of the European Union, 2015

Du Plessis M, Van Looy B, Song X, Magerman T, 'Data Production Methods for Harmonised Patent Indicators: Assignee sector allocation' (EUROSTAT Working Paper and Studies), Luxembourg, 2009.

EC Communication, 'Preparing for our future: Developing a common strategy for key enabling technologies in the EU', 2009, CELEX: 52009DC0512.

EC Communication, 'For a European Industrial Renaissance', 2014, CELEX : 52014DC0014.

EC Communication, 'Digitising European Industry Reaping the full benefits of a Digital Single Market', 2016, CELEX : 52016DC0180.

Freeman C, 'The Economics of Industrial Innovation'. London: Pinter Publishers, 1982.

Gkotsis P, 'The capability of the EU R&D Scoreboard companies to develop Advanced Manufacturing Technologies'. Joint Research Centre- IPTS Technical Reports, May 2015.

Grupp H, 'Foundations of the Economics of Innovation — Theory, Measurement and Practice'. Cheltenham: Edward Elgar, 1998.

IDEA Consult, ZEW, TNO, CEA, 'Feasibility study for an EU Monitoring Mechanism on Key Enabling Technologies: Report for the European Commission', DG Enterprise and Industry, 2013.

Lerner, J. 'The importance of patent scope: an empirical analysis.' The RAND Journal of Economics, vol 25(2), 319-333, 1994.

Magerman T, Grouwels J, Song X, Van Looy B, 'Data Production Methods for Harmonised Patent Indicators: Patentee Name Harmonisation' (EUROSTAT Working Paper and Studies), Luxembourg, 2009.

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

OECD, 'Emerging technologies' in OECD Science, Technology and Industry Scoreboard 2013: Innovation for Growth, OECD Publishing, 2013.

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

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

Appendix

Company-specific data, such as employment and R&D expenditure, came from the EU Industrial R&D Scoreboard, whereas patent data were based on PATSTAT. The matching procedure that was necessary for linking the PATSTAT entries with the Scoreboard companies is briefly presented.

PATSTAT

PATSTAT is a relational database that contains information about published patents from 83 patent authorities worldwide, dating back to the late 19th century; it is updated twice a year. All information that is provided on a patent application is included in the corresponding PATSTAT entry. In the original version of the database, the names of the applicants were in a 'raw format' taken directly from the patent application; this 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 harmonisation of all applicant names occurring in PATSTAT developed by the K.U. Leuven solved this problem (Du Plessis et al., 2009; Magerman et al., 2009; Peeters et al., 2009). The process of name harmonisation included 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'). This meant that patents could be more exactly assigned as belonging to a specific patent applicant, which minimised classification errors to a large extent.

The patents in this analysis were counted based on the application filing date. Patent applications that were filed in the EPO or the USPTO between 2010 and 2012 were used for the analysis of the internationalisation activities of firms that develop AMT-related technologies and for the analysis of complex patents. The data from PATSTAT were matched at the level of patent applicants in the harmonised version of the database with data from the EU Industrial R&D Scoreboard at the level of individual companies (including subsidiaries).

Table 11 Definition of AMTs based on IPC (IDEA Consult et al. 2013)

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 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, 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 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

The IPC is a hierarchical classification system used primarily to classify and search patent documents according to the technical fields to which they pertain. The classification scheme contains about 70 000 entries identified by classification symbols (IPC codes) that can be allotted to patent documents. These different classification codes

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).

For consistency with existing figures for patents relating to KETs and AMTs, we utilised the most recent definition of KETs that was developed by the KETs Observatory, in which AMT is a subfield of KET (IDEA Consult et al. 2013). The definition is based on the IPC.

Patent applications filed in the USPTO between 1972 and 2012 were examined in the analysis of the technical knowledge base to detect patterns and clusters that could suggest the emergence of new technologies.

The EU Industrial R&D Investment Scoreboard

The EU Industrial R&D Scoreboard is part of the European Commission's monitoring activity that aims to improve the understanding of trends in R&D investment by the private sector, and the factors affecting such investment. 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. 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 both the geographic and temporal coverage and the number of companies included. The target is to cover the world's top 2 500 R&D investors so that fastest-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 2 000 companies investing the largest sums in R&D in the world while maintaining an EU focus by also reporting on the top 1 000 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 expenditure, 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.

In the 2013 edition of the Scoreboard, companies' R&D rankings are based on information taken from their latest published accounts. For most companies, this corresponds to the data from calendar year 2012, but in a significant proportion of companies the financial year ended on 31 March 2013. In some of the included companies, the financial year ended as late as 30 June 2013, and a in a few cases only accounts to the end of 2011 were available.

List of abbreviations

AMT — advanced manufacturing technology

EPO — European Patent Office

ICB — Industry Classification Benchmark

ICT — information and communication technology

IPC — International Patent Classification

IPO — Intellectual Property Office

KET — key enabling technology

PATSTAT — Worldwide Patent Statistical Database

RoW — rest of the world

Telecomm — telecommunications

USPTO — United States Patent and Trademark Office

WIPO — World Intellectual Property Organisation

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