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Executive summary

Today it is widely recognised that a country's long-term economic growth and competitiveness are highly dependent on its ability to innovate. A decisive factor in fostering innovation is the production, accumulation and diffusion of knowledge as well as the interaction and connectedness of relevant actors. Research and Development (R&D) processes are a systematic approach towards knowledge generation, constituting the basis for economic prosperity. In this report, we analysed the patent activity of Japan and the member states of the European Union, with special emphasis on cooperation between these two regions. The United States, Japan and the EU are the regions with the highest knowledge production as measured in patent application output. Their specialisation and cooperation patterns are therefore of special interest in understanding global R&D networks.

The overall patenting activity under the Patent Cooperation Treaty (PCT) is higher in Europe than in Japan. This can mainly be attributed to the three biggest European countries, namely Germany, United Kingdom and France, whose inventors are producing about two-thirds of the European Union's output. However, the growth rate of patenting activity in Japan is higher than in Europe in general and than in single European countries with high output level in particular. The Japanese R&D output shows a specialisation in electrical engineering, especially in the fields of semiconductors and audio-visual technology. From the European countries, Germany invention output shows specialisation in mechanical engineering that is based on technologies for mechanical elements, engines, pumps, turbines and transport. In France and the UK, the technology field with the largest number of inventions is chemistry.

Looking at the co-inventions between Japanese and European inventors one major finding is apparent - the overall cooperation in patenting between these regions is very low. Out of more than one million patents developed by inventors of these countries only around, 2,600 were the result of a collaborative co-invention process between the Asian country and members of the European Union. Out of these around 2,300 are attributed to inventors based in Europe or Japan. For these jointly developed patents, there is a high level of concentration on country-level as well: 72% of all the inventors developing a patent together with a Japanese inventor stem from Germany, United Kingdom or France. Technology-wise more than 40% of the co-inventions fall into the "chemistry" section for both regions, this is a much higher share than chemistry's role in the overall patent portfolio of these regions. The network analysis indicates that the cooperation between Japan and Europe in knowledge development might be higher in sectors where both countries are having specialisation advantages, e.g. collaboration with the Nordic countries in electrical engineering. However, this is not true for all technologies. Additionally, the cooperation between Europe and Japan is often not bilateral but includes inventors from more than one European country whereby a Western European component is visible.

When looking at the applicants, who file the jointly developed patent applications, it is obvious that this kind of cooperation is driven by large enterprises like BASF, Ericsson or Panasonic. Additionally, the cooperation in general is concentrated on a limited number or actors. The Top-20 institutional applicants account for a little more than a third of all patents and all of these applicants are companies. Less than 8% of all joint co-inventions are filed by other legal institutions.

The second source of network data we analysed, international knowledge flows between inventors and applicant country, leads to similar findings. The knowledge flows are not very intensive (they most likely concern research laboratories of multinational corporations that file inventions with their headquarters as applicants). But at the same time, the flows between Japan and other European countries are at similar levels than those of medium-sized European countries. In total, and especially in electrical engineering, Japanese applicants file knowledge developed by European inventors more often than the other way round, which indicates a gain in knowledge for Japanese corporations due to these flows. However, this is not true for all technologies e.g. in chemistry European applicants profit from Japanese knowledge.

Altogether, the extent of interaction between these two knowledge spaces is rather limited given their size. The limited cooperation is concentrated between Japan and big or specialised European countries. The increasing complexity and convergence of technology, the different specialisation patterns in the countries' knowledge bases as well as the overall activity of both regions R&D systems constitute excellent conditions for expanding and deepening of cooperation with mutual benefit. However, as the cooperation is carried out by a limited set of (big) institutional actors the question is whether or not policy measures can have an effect on the strategic decisions of potential institutions.

However, due to the limitations of patent applications as innovation indicator, the result's implications in regard to policy recommendation should be approached with greatest caution and deliberation. Patents are just one among several possible outputs of research collaboration and they represent economic value in some cases, sometimes they only make strategic sense or the other way round – relevant inventions are not filed at all. For policy, the interesting question is whether and how the collaborative patents can be exploited and literature shows that, this varies from application to application. What this analysis shows are sectors and actors with relevant knowledge and specialisation advantages and that the cooperation between those is rather limited. However, Japan is known as a country with a less internationalised and collaborative knowledge production.

Intensified cooperation between specialised partners could be mutual beneficial but what the study cannot show, is if existing collaboration takes place on intra-firm (different locations of the same multinational) level or if the observed collaboration is on the inter-firm or inter-institutional level. If it is a policy goal to push open innovation in an international fashion, co-inventions can be a useful indicator for innovation in some sectors.

1. Research question and methodology

This introductory chapter presents the research questions, discusses the data basis and applied methodology including its limitations. In the first subchapter, we specify our research questions and provide a short overview of our data. In the second part of this chapter, we discuss the value of patent applications as indicators for innovative activity and lay out the methodology we used.

1.1 Research questions

With this report we give an overview of the patterns in EU-Japan collaborative research measured in patenting activity. Patent applications and patents have long been used as indicators of innovation output (cf. Griliches 1990; Nagaoka et al 2010). Conscious of the potentially misleading notion of innovation output, patent applications and patents are the most important indication of inventive activity and novel codified knowledge. Whether or not the inventive activity triggers innovations with actual economic or social impact is something that cannot be answered by patent statistics. With this limitation in mind, we make use of patent applications as an indicator of inventive activity in Europe and Japan.

- What is the dynamics of patenting activity in Europe and Japan for different technology fields?
- What are the specialisation patterns observable?
- What are the characteristics of EU-Japan cooperation in patenting activities?
- Who are the main actors of collaboration in international patenting between these two regions?

We aim to answer these questions on the basis of patent applications filed under the Patent Cooperation treaty (PCT). These applications often are called PCT-patents. We focus on patent applications and do not limit our analysis on granted patents as we are interested in knowledge production and international cooperation. The time frame of the analysis is defined as patent applications filed during the period of 2005-2014. This is necessary because information on PCT patent applications is only published 18 months after filing which causes a delay in the period a study like this can cover. Besides descriptive statistics, the methods of Revealed Technological Advantage (RTA) analysis and Social Network Analysis (SNA) are deployed to analyse the specialisation and international cooperation of patenting activities. SNA for inventor networks will be based on degree and eigenvector centrality on country level.

1.2 Data basis and methodology

The following analysis builds on PCT patent data received from European Patent Office's (EPO) PATSTAT database (version April 2016). PCT applications are generally better for international comparison than national applications as the procedures are standardised. The OECD Patent Statistics Manual[1] actually advises against comparing national level patent applications as scope and filing processes can differ substantially around the globe (affecting the numbers of application output). This is particularly important when including Japan in comparative analyses as the country has a system of national patenting that is different from most other regions.

The core of our analyses is the set of patent applications, which was developed by inventors either based in the EU or Japan and that was filed in the period from 2005 to 2014. While only patent

[1] http://www.oecd.org/sti/inno/oecdpatentstatisticsmanual.htm

applications are analysed, regardless if these applications have ever been granted, we use the term "patent" for reasons of readability. For our purposes, a patent application is a sufficient indication of novel, codified, potentially innovation-related knowledge that the applicants consider relevant enough to disclose.

Our core interest in this study lies in characterising not only patent application output as such, but also patterns of international cooperation in patent application output. During the last decades, an increase in the level of cooperation among researchers from different countries is observable, reflecting the greater openness and internationalisation of S&T activities. This information is found in patent documents, which list inventors from different countries. Patent applications with multiple inventors from different countries (or applications that are filed under more than one technology class) can either be attributed to each country (or class) as a whole or as a fraction, based on the total number of regional and technological entities. The methodological approach for the following analysis is the fractional-count method (Dernis and Guellec 2001).

1.2.1 Patent applications as an indicator

The Swiss Federal Institute of Intellectual Property (2014) defines patents as "titles conferring the right to an invention granted by intellectual property authorities. Legally, an invention is something that solves a technical problem with technology". The OECD's (2013) definition focuses less on the technology dimension and more on the aspects of publication and transfer of rights: „A patent is a right granted by a government to an inventor in exchange for the publication of the invention; it entitles the inventor to prevent any third party from using the invention in any way, for an agreed period".

Patents can thus be seen as an outcome of inventive and often research-intensive activity that is used most often by firms in order to protect and codify new knowledge. At the same time, patents are public and the knowledge they contain can thus be used to inspire further inventive activity[2].

From an innovation analyst's perspective, literature has long discussed the value of patents in order to assess innovation performance (e.g. Griliches 1990, Nagaoka et al. 2010). As the direct outcome of inventive processes aiming at commercial impact, patents seem to be an appropriate indicator to capture technological change, particularly the latter's competitive dimension (cf. Archibugi/Pianta 1996, 452). As filing patents is a costly process, it can be expected that applications are filed "for those inventions which, on average, are expected to provide benefits that outweigh these costs" (ibid., 453).

A number of drawbacks of patents as innovation indicators are also apparent, though: Not all inventions are technically patentable (software in most cases), neither are all technically patentable inventions patented. This depends on the sectors as well as on the specific technologies. Firms might opt to avoid the time and resource-consuming patenting process for strategic reasons. Their propensity to patent innovation varies. Furthermore, decisions on who features as inventor and as applicant (i.e. the owner of the intellectual property) or where a patent is filed first are strategically taken, which analysts need to keep in mind when drawing conclusions. Additionally, a granted patent only represents an economic value if it is exploited. Studies using survey methodology to get information on the usage and commercialisation of a limited set of patents estimate that around 40%

[2] Whether or not the knowledge codified in patents is enough to follow up on the research that they embody, or whether significant tacit knowledge would be needed to do so, is a separate question that we will not discuss here.

of patents reach the market launch stage (Webster/Jensen 2011) or that around 65% of inventions involving academics are commercially used (Meyer 2006)[3]. In the early 2000s, the European PatVal-EU 1 Survey questioned the inventors of 9,017 patents granted by the European Patent Office (EPO) between 1993 and 1997 and found, among other observations, that around 36% of the patents are not used in any economic activities (Giuri et al. 2007). Among the patents that are commercially used, there exists a significant difference in their economic impact as Pakes and Griliches (1984) or Scherer and Harhoff (2000) have already pointed out. A very small number of patents is responsible for the largest part of the economic value in a firm's or a country's patent portfolio.

With these limitations in mind, patents can be an informative and relevant indication of inventive as well as research and development activity and a proxy pointing to economic and intellectual potential for innovation. This also and especially applies to collaboration in applied research, technology development and inventive activity.

Most patenting activity is firm-based, there is, indeed, some indication in patent data, which can give us additional meta-level insights into transnational activities of firms: Apart from patent applications with inventors from two or more countries, there are patents where the applicant is from a different country than one or several of the inventors. This indicates knowledge flow out of the country of the inventor(s) and into the country of the applicant, i.e. towards the owner of the intellectual property (IP). Guellec and van Pottelsberghe de la Potterie (2001) showed that the share of this kind of foreign ownership of patents is more frequent than co-inventions (12% already in 1995). We can thus distinguish two major forms of international collaborative patenting activity:

- **Co-inventions**: Co-inventions represent the international collaboration in the inventive process. International collaboration by researchers can take place either within a multinational corporation (with research facilities in several countries) or through cooperative research among several firms or institutions (collaboration between inventors belonging to different universities or public research organisations). In that sense, co-invention indicators also reflect international flows of knowledge.
- **Foreign ownership**: Cross-border ownership of patent applications and patents reflects international flows of knowledge from the inventor country to the applicant countries and international flows of funds for research (multinational companies). In most cases, patents with inventors from abroad correspond to inventions made at the research laboratories of multinational companies and applied for at company headquarters (although in some cases national subsidiaries also may own or co-own the patents). Hence, this indicator expresses the extent to which foreign firms control domestic inventions.

Co-ownership (or co-application) would be a third kind of collaborative patenting: the presence of applicants from different countries in the same patent application. This also occurs, but it is considered a separate topic and is of limited interest to us here. There is literature discussing patterns of and reasons for patent co-applications (e.g. Hagedoorn, 2003). It points to strong sectoral differences in co-applications that seem to be rooted in some sectors providing more legal security for firms to engage in co-applications as a kind of ex-ante sharing of intellectual property.

We distinguish two relevant kinds of collaborative patent applications (co-patents): Co-inventions, indicating networks engaging in collaborative invention-oriented activities, and foreign-owned

[3] mostly if they are produced already in collaboration with industry; of the purely academic inventions, only between 10 and 40% are commercially utilised

applications where the inventors and applicants are from different countries, indicating knowledge flow networks.

In order to make the international comparison of patent output possible, the patent classification system developed by the Fraunhofer ISI, the Observatoire des Sciences et des Technologies and the French Patent Office (INPI) is used (Schmoch, 2008). This patent classification system is based on the codes of the International Patent Classification (IPC). It is comprised of 5 technology sections (electrical engineering, instruments, chemistry, mechanical engineering and other fields) that are broken down in 35 smaller technology fields.

Table 1: Technological classification of patents by technology sections and technology fields

No.	Name of Section	Name of Field
1	Electrical engineering	Electrical machinery, apparatus, energy
2		Audio-visual technology
3		Telecommunications
4		Digital communication
5		Basic communication processes
6		Computer technology
7		IT methods for management
8		Semiconductors
9	Instruments	Optics
10		Measurement
11		Analysis of biological materials
12		Control
13		Medical technology
14	Chemistry	Organic fine chemistry
15		Biotechnology
16		Pharmaceuticals
17		Macromolecular chemistry, polymers
18		Food chemistry
19		Basic materials chemistry
20		Materials, metallurgy
21		Surface technology, coating
22		Micro-structural and nano-technology
23		Chemical engineering
24		Environmental technology
25	Mechanical engineering	Handling
26		Machine tools
27		Engines, pumps, turbines
28		Textile and paper machines
29		Other special machines
30		Thermal processes and apparatus
31		Mechanical elements
32		Transport
33	Other fields	Furniture, games
34		Other consumer goods
35		Civil engineering

Schmoch, 2008

With the aim of providing a classification system as consistent and systematic as possible, the classification used exclusively the codes of the International Patent Classification and covered all inherent technology fields in a balanced way by using an appropriate level of differentiation to avoid too large, too small and overlapping technology fields. Due to these characteristics, the patent classification system is well-suited to serve as a basis for the analysis of country structures and international comparisons, notably for the determination of specialisation profiles. Equipped with these conceptual clarifications, we can now continue with the methodological approach of the analysis.

1.2.2 Methodology and indicators

The aim of this study is to analyse the cooperation in research and technology development between researchers and institutions in Europe and Japan, with a special focus on the specialisation of the research systems and the international flows of knowledge. The data basis for this endeavour is the output of PCT patent applications on country level between 2005 and 2014. In this analysis, we distinguish between the inventor and the applicant level. The geo-location of the applications is based on the home address of the inventor, normally close to the location of invention, and the address of the filing entity, which in most cases is the institution owning the patent (unless ownership was transferred at a later stage). These two locations do not necessarily have to be in the same country. For example, the patent could be filed using the headquarters address while the actual research has been carried out at a different branch.

First, we will give a descriptive overview of the output of the covered countries before analysing the countries' specialisations deploying a Revealed Technological Advantage (RTA) analysis (cf. eg., Soete 1987, Patel/Pavitt 1987, Patel/Vega 1999 or Le Bas/Sierra 2002). To illustrate the knowledge flows between EU and Japan we will also use instruments of the Social Network analysis (SNA), visualising the research networks and calculating different centrality indices on the countries' positions within the networks (cf. e.g., Constantelou et al. 2004, Breschi/Lissoni 2004, Maggioni et al. 2007, Scherngell/Barber 2008, Ter Wal/Boschma 2008, Heller-Schuh et al. 2011, or De Prato/Nepelski 2012).

Revealed Technological Advantage

The revealed technological advantage index is defined as the share of an economy's patents in a particular technology field relative to the total patents in that economy (OECD 2013). The RTA index is a specialised version of the Revealed Comparative Advantage (RCA) index developed by Balassa in 1965. Soete (1987) first used the RTA index for a comparative study scrutinising the effect of technological performance, measured by patent output, on international trade. Patel and Pavitt (1987) deployed the RTA index in a study comparing the technological capability of different countries while Patel and Vega (1999) as well as Le Bas and Sierra (2002) used the index, on a disaggregated technological level, for studies on location decisions of multinational enterprises whereas the focus was set on technological profiles. In this study, we use the RTA index to prepare technological specialisation profiles of European countries and Japan. This will provide information of technological strengths and weaknesses of the countries innovations systems. The index is calculated on national level for all 35 technology fields. The RTA index is defined as:

$$R_{ij} = \frac{y_{ij}}{\sum_{i=1}^{I} y_{ij}} \bigg/ \frac{\sum_{j=1}^{J} y_{ij}}{\sum_{i=1}^{I}\sum_{j=1}^{J} y_{ij}} \qquad (1)$$

where y_{ij} denotes the patent activity in country *i* (*i* = 1, …, *I*) and technology field *j* (*j* = 1, …, *J*). The RTA index R_{ij} is the ratio between the share of patents observed for country *i* in technology field *j* and the sum of all patents in this technology field, and the share of all patents in this country on all patents in all countries taken into account. The RTA index varies around unity, such that values greater than one indicate a country's relative strength, and values below unity a relative weakness. The index is equal to zero when the country has no patents in a given field; is equal to 1 when the countries share in the sector equals its share in all fields (no specialisation).

When interpreting results from a RTA analysis two points of criticism have to be taken into account. First, if the overall number of patents is small, the analysis might result in extreme values for some entities and therefore could be misleading. Second, small countries, in general, are more specialised than bigger ones where the overall output is higher. This could lead to a higher ranking even though their importance in absolute numbers in rather small (Le Bas/Sierra 2001). Therefore, a descriptive analysis will be conducted before discussing the results of the RTA analysis and furthermore, methods from the Social Network Analysis will be used to triangulate the results and give an informed picture of the technological performance of the EU-Japan cooperation.

Social Network analysis

Social network analysis is a set of methods and techniques for investigating social structures through the use of network and graph theories. From the view of SNA, the social environment can be expressed as patterns in relationships among different units. It characterises network structures in terms of nodes and edges that connect them (Wasserman/Faust, 1994). In recent years, SNA has been exploited to analyse the structure and dynamics of R&D networks (cf. Scherngell, 2014). In this context, the relationship between innovating entities in form of people, organisations, regions or countries is scrutinised based on project, publication or patenting data.

These networks most often are described using graph theoretic or sociometric notions. Within graph theory, networks consist of actors (nodes) and their relationships (edges). In this analysis, we define inventors as actors represented by nodes which stand in a relationship and are connected with each other through an edge if they jointly developed a patent. As we aggregate data on country level, each unit may be connected by a multitude of links. To capture the cooperation intensity, these links will be weighted by the number of patent applications between two entities. Therefore, our graph consists of a set of nodes, a set of edges and a set of weights and it can be described as (Wasserman/Faust, 1994; Brandes/Erlebach, 2005; Carrington et al., 2005):

$$G = \{N\ ,\ L\ ,\ W\} \tag{2}$$

whereby

$N = \{n_1, n_2, \ldots, n_G\}$, $L = \{l_1, l_2, \ldots, l_L\}$ and $W = \{w_1, w_2, \ldots, w_L\}$

and n_g with g=1,…, G describes elements of the set of nodes N, l_L with l=1,…, L are elements of the set of edges and w_L with l=1,…, L are the weights which are attributed to the set of edges. An edge l between two nodes u and v is defined as:

$$l_q=(n_u n_v) \text{ for } q=1,\ldots, L \text{ and } u, v =1,\ldots, G. \tag{3}$$

Additionally, networks can also be described by a sociomatrix or adjacency matrix $X=(x_{uv})$. This notion is especially useful for defining measures like centrality, which will constitute the core of this analysis. In a sociomatrix the elements x_{uv} represent the intensity of interaction between the two elements n_u and n_v. The aim of the study is to identify the most important actors and links within the co-invention network. The relevance of the actors will be calculated by measures describing their position within the network. These measures are based on the number of edges (degree) each node has. In SNA these measures are summarised under the terms centrality (Wasserman/Faust, 1994; Brandes/Erlebach, 2005).

The simplest definition of actor centrality is that central actors must be most active in the sense that they have the most ties to other actors in the network. An actor with a high centrality level, as measured by degree centrality, is "where the action is" in a network. Thus, this measure focuses on the most visible actors in the network. The degree of a node n_u is defined by the number of its edges. In weighted networks, like ours, the number of edges is multiplied with its weights. The degree centrality $C'_D(n_u)$ can be calculated by standardising the degree by dividing the number of nodes within the network (Wasserman/Faust, 1994):

$$C'_D(n_u) = \frac{\sum_{\substack{v=1 \\ u \neq v}}^{G} x_{uv}}{G-1} \tag{4}$$

A second centrality measure we use is the eigenvector centrality developed by Bonacich (1987). The basic thought behind this measure is, that the centrality of every single actor is depending on the centrality of actors it is connected with. Thus, the importance of nodes increases if they are neighbouring other important nodes or connected to a multitude of other actors. In a graph the eigenvector centrality $C_E(n_u)$ of a node n_u is defined as (Faust, 1997):

$$C_E(n_u) = \frac{1}{\lambda} \sum_{v=1}^{G} x_{uv}\, c_v \tag{5}$$

where λ is the largest eigenvalue of the GxG-adjacency matrix X. This definition implies feedback effects. In order to create unambiguousness, the eigenvector centrality is defined as eigenvector for the largest eigenvalue λ.

The introduced centrality measures will be applied in the empirical analysis to determine the centrality of European countries and Japan in a network of co-inventions. Thus, the innovative capability of these countries will be assessed not only using the RTA, a classic specialisation index, but also from the point of network theory.

2. European and Japanese patenting activity

In this chapter, the patenting activity of European and Japanese actors is scrutinised. Patent data has some features one has to be aware of when conducting an analysis on this information basis. There are two types of actors involved in producing knowledge codified as patent applications: one or several inventors and one or several applicants. While the inventors are the individuals that developed the knowledge, the applicants (often companies) are the ones who register and therefore own it. Particularly when discussing where a certain patent application was created, it is important to always keep in mind what level one is referring to, the level of the inventors of the knowledge or the owners of the knowledge. Therefore, the following chapter is structured not only by the type of analyses conducted but also by differentiating inventor and applicant level.

2. 1 Patent activity of inventors and applicants

This subchapter gives a descriptive overview of the patenting activity of the European and Japanese actors. Technological-wise the patents are analysed on basis of the technology field classification. The section is divided into two parts. In the first, we are discussing the inventor level and in the second the applicant level. The total output on country level for the period 2005-2014 as well as the development during that time is discussed.

2.1.1 Patenting activity of European and Japanese inventors

Inventors based in Japan and the EU member state countries developing patents account for around 760,000 patents during the period 2005 to 2014: European inventors account for 481,000, while Japanese inventors account for more than 279,000 applications. Based on the technology field classification system, these patents are attributed to the five broader technology sections and 35 narrower technology fields. Differences between the regions are clearly visible on the more detailed level, but can already be observed on the technology section level as well.

While more than third (35%) of Japan’s patents belong to the electrical engineering section, only less than one-fourth (24%) of European Union's patents were developed in this technology section between 2005 and 2014. These shares are inversely allocated in case of mechanical engineering section where 27% of the European patents and 21% of the Japanese patents were developed in this timeframe. There are no significant differences in the instruments and chemistry sections between EU28 and Japan (16% and 24%; 15% and 26% respectively). However, only 3% of the Japanese patents can be categorised into other technology fields, while this share is around 8% in case of European countries, revealing a higher significance of these fields in Europe ("furniture, games", "civil engineering" and "other consumer goods").

In terms of absolute numbers, Japan is ahead of all European countries in the electrical engineering, instruments and chemistry technology sections; there was comparatively the same number of patents in the mechanical engineering field in Germany and Japan (around 58,000 and 59,000 respectively) in the given timeframe, while Germany has a slight lead over Japan in the other categories (around 11,000 patents compared to 9,000 patents). As expected, Germany, France and the United Kingdom are the three top European countries with the most patents in all technology sections, with Germany having in all sections more than double of the patents than the country with the second highest number (France in electrical engineering, chemistry and mechanical engineering; and the United Kingdom in the instruments and other categories).

Just by focusing on the absolute numbers of patents belonging to a specific technology section, we can already observe the relative strengths of some countries: Sweden and Finland are strong in the electrical engineering section (11,334 and 7,838 patents respectively), while Spain and Belgium produce a high number of patents in the chemistry section (5,104 and 4,911 patents respectively) compared to their achievements in other sections. Generally the Netherlands and Italy are the strongest actors after the top 3 countries: the Netherlands has a particularly high number of patents in the instruments section (6,427 patents), while Italy produced a number of patents (10,311 patents) close to the total number of the United Kingdom (11,190 patents) in the mechanical engineering section.

Table 2: Number of patent applications from all European and Japanese inventors by technology section, 2005-2014

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	Total
Austria	2,846	1,680	2,818	3,969	1,535	12,849
Belgium	2,330	1,464	4,911	2,414	839	11,959
Bulgaria	87	39	70	107	52	355
Cyprus	16	17	27	15	15	89
Czech Republic	302	235	614	506	176	1,833
Germany	36,732	26,310	43,434	58,061	11,255	175,792
Denmark	2,076	2,041	3,899	2,800	1,006	11,822
Estonia	114	65	95	42	13	330
Spain	2,599	2,190	5,104	3,975	2,084	15,952
Finland	7,838	1,514	2,495	3,050	726	15,623
France	16,677	10,006	19,521	19,203	4,645	70,052
United Kingdom	14,785	11,133	15,972	11,190	6,354	59,435
Greece	182	129	296	287	108	1,003
Croatia	79	66	183	121	78	526
Hungary	688	271	728	429	162	2,278
Ireland	1,182	978	744	537	275	3,715
Italy	4,376	4,130	7,856	10,311	4,584	31,258
Lithuania	34	45	74	48	31	231
Luxembourg	89	61	125	201	29	505
Latvia	27	25	117	45	21	236
Malta	8	0	8	6	8	30
Netherlands	9,285	6,427	8,095	5,154	2,080	31,042
Poland	475	281	787	529	255	2,328
Portugal	209	179	426	250	143	1,208
Romania	175	63	64	112	45	459
Sweden	11,334	4,052	4,510	6,853	1,904	28,652
Slovenia	176	128	444	231	257	1,236
Slovakia	105	38	106	150	46	445
EU28	114,825	73,570	123,524	130,598	38,725	481,243
Japan	97,382	45,203	67,922	59,467	9,131	279,104

Source: EPO 2016

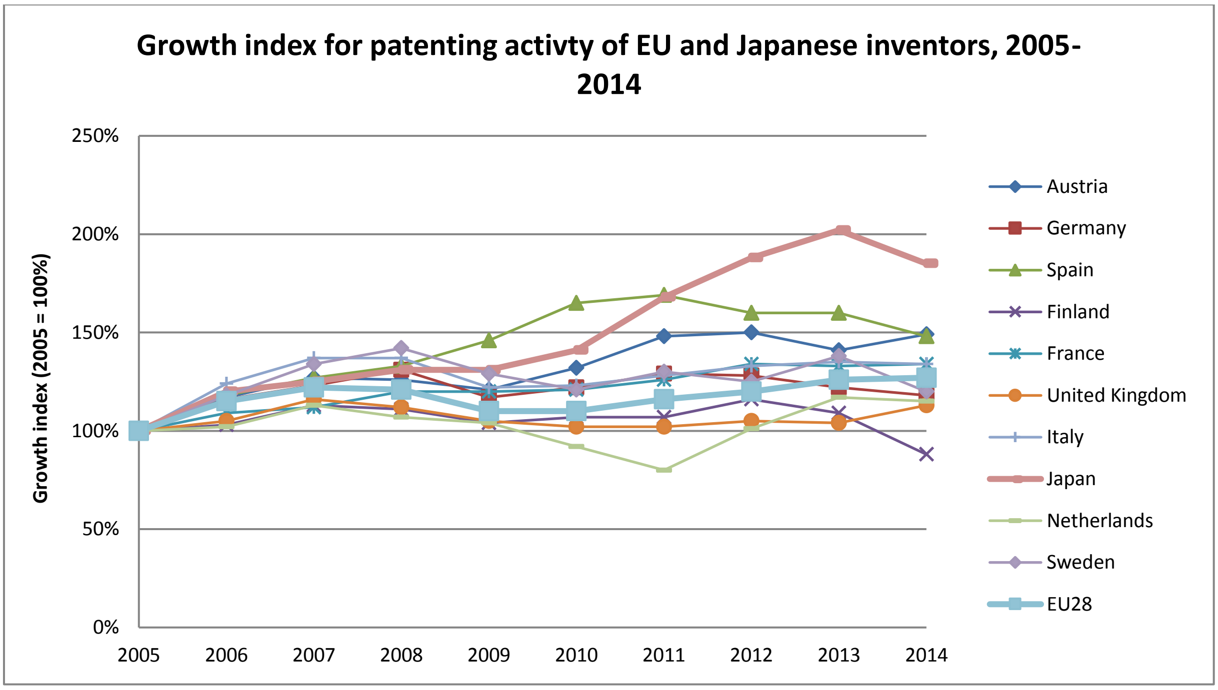
The European landscape of patents in terms of inventors is very concentrated: German inventors developed more than a third of all patents in the European Union (36.5%), followed by France and the United Kingdom (14.5% and 12.3% respectively). Nearly two-thirds of all patents invented stem from the three biggest EU countries, i.e. Germany, France and the United Kingdom. Their joint output was around 305,000 in the given timeframe, which exceeds a bit Japan's 279,104 patents. German inventions are focused on mechanical engineering (33%) and chemistry (25%). The most inventions from France and UK are patented under the chemistry section (27% and 28% respectively).

If we look at the technology field level, we can observe the leading role of Japanese inventors in many areas over the EU28 countries: Japan has a much higher proportion of patents in the fields of "electrical machinery, apparatus, energy" (10.4% in comparison to EU28's 6.4%), "audio-visual technology" (5.2% in comparison to EU28's 2.2%), "semiconductors" (6.3% in comparison to EU28's 2.0%), "optics" (5.3% in comparison to EU28's 1.9%), "macromolecular chemistry, polymers" (3.4% in comparison to EU28's 2.1%) and "materials, metallurgy" (3.1% in comparison to EU28's 1.9%).

Meanwhile the EU28 countries have a significantly higher share of patents in "digital communication" (5.0% in comparison to Japan's 2.9%), "pharmaceuticals" (4.6% in comparison to Japan's 2.8%), "medical technology" (5.7% in comparison to Japan's 4.4%), "handling" (3.3% in comparison to Japan's 2%) and "civil engineering" (3.5% in comparison to Japan's 1.0%). The latter explains the relative European significance of the "other" technology sector.

Regarding the development of patent activity per inventors over the given timeframe, we can first observe that the Japanese output per year is increasing with higher dynamics than in the member states of the European Union and as a consequence the whole EU. While Japanese inventors nearly doubled the annual activity between 2005 and 2014, the EU28 countries overall had a growth rate of 27%. There are, however, significant differences among the key member states in Europe. Spain and France show a considerable growth rate with almost 50% during the period of 2005–2014, other countries lag behind, e.g. the growth rate of Finland shrank (-12%) and the United Kingdom, the Netherlands, Sweden and Germany almost stagnated in this timeframe. The overall growth was mainly pulled by France (from the top 3 patenting countries) and the new member states of the EU, such as Bulgaria, the Czech Republic, Estonia, Malta, Poland, Romania, Slovenia and Slovakia that at least doubled their output which is evidently still in a much smaller scale of absolute numbers.

Figure 1: Growth index for the development of the patenting activity of inventors from 10 European countries and Japan, 2005-2014



Source: EPO 2016

The concentration of patents can be observed in the level of technology fields as well. The biggest three EU member states (Germany, France and the United Kingdom) combined, account for less than 50% of all European patents only in 2 out of 35 technology fields: "digital communication", and "food chemistry" (47% and 44% respectively). Some extreme concentration levels (around 75%) can be seen in the case of technology fields “basic materials chemistry”, “engines, pumps, turbines”, “mechanical elements” and “transport”.

Table 3: Number of patent applications from all European and Japanese inventors by technology section, 2005-2014

Technology Field	Japan	EU28	Germany	France	United	Japanese	EU28
Electrical machinery, apparatus, energy	29,049	30,963	15,040	3,712	2,729	10,4%	6,4%
Audio-visual technology	14,386	10,671	2,950	1,603	1,318	5,2%	2,2%
Telecommunications	6,992	10,597	2,340	1,585	1,524	2,5%	2,2%
Digital communication	8,215	24,075	4,490	3,430	3,315	2,9%	5,0%
Basic communication processes	2,531	3,448	1,078	633	416	0,9%	0,7%
Computer technology	16,013	21,519	5,465	3,711	3,682	5,7%	4,5%
IT methods for management	2649	3782	760	515	921	0,9%	0,8%
Semiconductors	17,547	9,771	4,608	1,490	880	6,3%	2,0%
Optics	14,852	8,925	3,426	1,354	1,100	5,3%	1,9%
Measurement	12,374	24,212	9,942	3,772	3,427	4,4%	5,0%
Analysis of biological materials	1,663	5,443	1,577	830	1,027	0,6%	1,1%
Control	3,913	7,677	3,026	1,007	1,068	1,4%	1,6%
Medical technology	12,400	27,313	8,340	3,043	4,512	4,4%	5,7%
Organic fine chemistry	7,499	18,801	7,013	3,865	2,731	2,7%	3,9%
Biotechnology	5,619	14,966	3,920	2,385	2,212	2,0%	3,1%
Pharmaceuticals	7,844	22,260	5,585	3,549	3,739	2,8%	4,6%
Macromolecular chemistry, polymers	9,366	9,891	4,427	1,416	595	3,4%	2,1%
Food chemistry	2,588	5,095	913	744	597	0,9%	1,1%
Basic materials chemistry	8,848	13,879	6,324	1,581	2,230	3,2%	2,9%
Materials, metallurgy	8,697	9,240	3,664	1,685	696	3,1%	1,9%
Surface technology, coating	7,558	7,183	3,186	1,054	667	2,7%	1,5%
Micro-structural and nano-technology	386	746	257	141	64	0,1%	0,2%
Chemical engineering	5,078	13,847	5,407	1,882	1,606	1,8%	2,9%
Environmental technology	4,440	7,616	2,738	1,221	834	1,6%	1,6%
Handling	5,608	16,084	5,060	1,982	1,790	2,0%	3,3%
Machine tools	6,539	12,117	6,163	1,235	849	2,3%	2,5%
Engines, pumps, turbines	8,994	20,242	9,977	3,065	1,946	3,2%	4,2%
Textile and paper machines	4,675	8,128	2,972	702	715	1,7%	1,7%
Other special machines	7,029	15,695	5,394	2,227	1,441	2,5%	3,3%
Thermal processes and apparatus	4,286	8,549	3,130	1,183	655	1,5%	1,8%
Mechanical elements	8,683	20,384	11,280	2,614	1,656	3,1%	4,2%
Transport	13,652	29,400	14,085	6,195	2,138	4,9%	6,1%
Furniture, games	3,066	10,878	2,825	1,171	1,893	1,1%	2,3%
Other consumer goods	3,237	10,878	3,668	1,516	1,601	1,2%	2,3%
Civil engineering	2,827	16,969	4,762	1,958	2,859	1,0%	3,5%

Source: EPO 2016

Co-inventions between European countries and Japan

Following the analysis of the absolute numbers and development of patenting activity per country, technology field and technology sector, our attention is focused on the actual co-inventions between Japanese inventors and inventors from member states of the European Union. For this purposes, the analysis has been limited to patents that are the result of cooperation of at least one European and one Japanese inventor.

In the following tables, we give a brief overlook about the number of co-inventions jointly developed by European and Japanese inventors during the period 2005-2014. Overall, the shares of these collaborative patents are attributed to European countries more often (17%) than to Japan, which means the more European inventors were involved in the inventive process. The leading European countries are Germany, Great Britain and France in terms of absolute numbers (Germany being the first in all sections, the United Kingdom being the second in the instruments, electrical engineering and other section, while France being the second in the chemistry and mechanical engineering sections), while the new member states of the EU – with the exception of Hungary – are seriously lagging behind the old member states. In terms of the overall number of co-inventions, Hungary follows the most innovative countries in the mechanical engineering and instruments technology sections (8th highest number in both cases). Similarly, Denmark shows a high number of co-inventions in the chemistry section (15.46; rank 7) and Austria in the electrical engineering section (8.7; rank 7), meaning that these countries follow the absolute number of patents developed by the overall top countries (Germany, United Kingdom, France, Netherlands, Belgium, Italy).

Table 4: Co-inventions between EU and Japan by inventors' country and technology section, 2005-2014

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	Total
Austria	8.70	1.79	4.64	0.65	0.00	15.79
Belgium	14.26	9.58	34.41	6.09	0.83	65.16
Bulgaria	0.92	0.17	0.00	0.17	0.00	1.25
Czech Republic	1.05	0.36	0.71	0.64	0.00	2.76
Germany	154.40	39.02	234.99	62.94	5.19	496.54
Denmark	8.22	1.01	15.46	0.63	0.00	25.32
Spain	1.62	0.87	11.23	0.10	0.75	14.57
Finland	64.81	1.05	2.45	2.55	0.00	70.85
France	21.74	13.18	89.02	38.23	8.90	171.07
United Kingdom	101.09	16.97	78.20	36.18	11.15	243.59
Greece	0.00	1.57	1.19	0.35	0.00	3.12
Croatia	0.50	0.00	0.00	0.00	0.00	0.50
Hungary	3.28	2.62	2.84	2.87	0.00	11.62
Ireland	2.08	0.50	0.83	0.20	0.00	3.62
Italy	5.52	3.31	15.74	3.86	3.76	32.19
Luxembourg	1.17	0.00	0.00	0.00	0.00	1.17
Netherlands	6.30	5.50	16.11	9.71	1.41	39.03
Poland	3.53	0.00	4.33	0.08	0.00	7.94
Portugal	0.00	0.00	0.99	0.00	0.00	0.99
Romania	1.33	0.00	0.00	0.25	0.00	1.58
Sweden	42.76	5.39	8.94	5.04	0.17	62.29
Slovenia	0.00	0.00	0.85	0.00	0.00	0.85
EU28	443.29	102.88	522.94	170.53	32.16	1271.79
Japan	337.71	107.62	449.91	154.18	34.30	1083.71

Source: EPO 2016

An extreme level of concentration persists with regard to co-inventions on country-level as well: 72% of all the inventors developing a patent together with a Japanese inventor stem from Germany, United Kingdom or France, while 3 countries (Croatia, Portugal, Slovenia) do not even reach 1 co-invented patent and 3 other countries (Bulgaria, Luxemburg, Romania) are just over 1 patent. Focusing on the technology sectors, more than 40% of the co-inventions fall into the "chemistry" section for both regions, indicating a high significance. There are no relevant differences between the share of co-inventions on the Japanese and European side, "electrical engineering" is a bit more significant (+4%) in Europe, while "instruments" are more important in Japan (+2%).

On the level of the narrower technology fields, we can observe that the Japanese and EU28 shares in co-invented patents do not really differ in most of the fields. There are only three technology fields where a more than 1% difference between the Japanese and EU co-invention shares exist: Europe leads in "digital communication" and "basic materials chemistry", while Japan is stronger in "macromolecular chemistry and polymers". There are also some relevant differences in technological fields “measurement”, “pharmaceuticals”, “environmental technology”, “engines, pumps and turbines” and “civil engineering” where Japan and technological fields “electrical machinery, apparatus, energy”, “chemical engineering” and “transport” where the EU28 has a slight edge.

Table 5: Number of co-inventions from all European and Japanese inventors by technology field, 2005-2014

Technology Field	Japan	EU28	Germany	France	United Kingdom	Japanese share	EU28 share
Electrical machinery, apparatus, energy	55.28	72.51	33.89	6.88	16.54	5.10%	5.70%
Audio-visual technology	17.15	21.92	4.92	1.88	2.90	1.58%	1.72%
Telecommunications	32.26	39.13	11.89	1.63	5.73	2.98%	3.08%
Digital communication	142.17	201.50	73.82	4.55	46.76	13.12%	15.84%
Basic communication processes	3.13	4.85	2.66	0.67	1.03	0.29%	0.38%
Computer technology	40.44	47.06	8.98	2.76	13.43	3.73%	3.70%
IT methods for management	8.63	10.25	1.58	0.00	3.66	0.80%	0.81%
Semiconductors	38.63	46.26	16.65	3.38	11.05	3.56%	3.64%
Optics	23.97	25.25	9.95	4.10	2.84	2.21%	1.98%
Measurement	42.80	40.78	12.41	6.85	10.31	3.95%	3.21%
Analysis of biological materials	10.96	9.28	2.56	1.12	1.72	1.01%	0.73%
Control	7.33	6.50	2.81	0.11	0.66	0.68%	0.51%
Medical technology	22.56	21.07	11.29	1.00	1.44	2.08%	1.66%
Organic fine chemistry	102.00	123.58	63.74	34.16	12.49	9.41%	9.71%
Biotechnology	43.00	45.68	14.45	3.48	4.59	3.97%	3.59%
Pharmaceuticals	66.02	66.33	20.05	9.55	19.43	6.09%	5.21%
Macromolecular chemistry, polymers	75.75	64.80	25.43	14.46	7.09	6.99%	5.09%
Food chemistry	10.53	12.55	1.81	2.94	2.40	0.97%	0.99%
Basic materials chemistry	59.95	101.44	66.20	9.77	14.23	5.53%	7.97%
Materials, metallurgy	25.80	30.22	11.20	4.41	4.43	2.38%	2.38%
Surface technology, coating	22.13	25.59	12.14	3.92	4.35	2.04%	2.01%
Micro-structural and nano-technology	0.96	0.88	0.75	0.08	0.06	0.09%	0.07%
Chemical engineering	26.89	37.42	14.75	4.40	7.63	2.48%	2.94%
Environmental technology	16.89	14.54	4.47	1.86	1.50	1.56%	1.14%
Handling	9.47	10.70	0.89	0.65	3.08	0.87%	0.84%
Machine tools	9.63	9.54	3.16	2.63	1.80	0.89%	0.75%
Engines, pumps, turbines	36.79	35.63	9.71	3.57	19.52	3.39%	2.80%
Textile and paper machines	8.57	7.58	3.31	0.01	2.95	0.79%	0.60%
Other special machines	20.21	22.70	7.16	4.77	3.71	1.86%	1.78%
Thermal processes and apparatus	12.97	10.64	3.00	2.55	0.17	1.20%	0.84%
Mechanical elements	18.33	18.90	10.21	3.96	2.31	1.69%	1.49%
Transport	38.22	54.84	25.51	20.10	2.64	3.53%	4.31%
Furniture, games	4.07	3.87	0.57	0.67	1.50	0.38%	0.30%
Other consumer goods	12.44	13.99	1.63	2.21	5.45	1.15%	1.10%
Civil engineering	17.79	14.30	3.00	6.0	4.20	1.64%	1.12%

Source: EPO 2016

2.1.2 Patenting activity of European and Japanese institutions

Applicants, including inventors who are filing or co-filing their inventions, registered in one of the EU28 countries account for a total of more than 780,000 patent applications during the period 2005 to 2014 and Japanese applicants account for more than 300,000 applications. The total number of unique applicant names in the database is exceeding 620,000 entries. Based on the developed technology, these patents are attributed to the five technology sections and 35 technology fields. Differences between the regions industrial knowledge base can already be observed at this highly aggregated level. The European applicants file a quarter of their patents in the "electrical engineering", "chemistry" and "mechanical engineering" sections each and fourth quarter is distributed between the "instruments" and "other fields" sections, whereas first has a share around 15%. In contrast, Japanese applicants file more than a third (38%) of their patents under the "electrical engineering" section and have a lower share (21%) under the "mechanical engineering" section. In both regions, the share of "instruments" accounts for 15% to 16% and only 3% to 8% of all applications fall into the "other fields" section.

Table 6: Number of patent applications from all European and Japanese applicants by technology section, 2005-2014

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	Total
Austria	2,567	1,488	2,825	3,685	1,532	12,097
Belgium	1,826	1,369	4,751	2,245	953	11,143
Bulgaria	76	34	67	103	48	329
Cyprus	46	33	78	56	39	251
Czech Republic	224	205	590	464	161	1,644
Germany	35,558	25,866	42,617	58,267	11,092	173,401
Denmark	1,839	2,046	4,089	2,878	1,033	11,886
Estonia	91	67	97	47	14	316
Spain	2,327	2,156	4,982	3,792	2,020	15,276
Finland	8,839	1,515	2,620	3,182	731	16,888
France	18,189	9,865	19,165	18,260	4,654	70,133
United Kingdom	13,313	10,210	15,269	10,432	6,249	55,474
Greece	132	117	267	283	100	899
Croatia	71	61	164	113	74	483
Hungary	464	258	664	359	153	1,899
Ireland	1,051	963	948	554	315	3,831
Italy	3,783	3,913	7,350	9,834	4,168	29,048
Lithuania	35	45	73	47	29	229
Luxembourg	322	279	355	435	146	1,536
Latvia	29	29	111	47	21	237
Malta	24	80	47	30	21	203
Netherlands	10,527	7,209	9,205	5,174	2,444	34,559
Poland	341	261	747	477	248	2,074
Portugal	188	173	408	233	142	1,145
Romania	116	55	58	75	39	342
Sweden	13,197	4,109	4,462	7,274	2,067	31,109
Slovenia	159	119	437	220	210	1,145
Slovakia	90	38	94	139	44	405
EU28	115,424	72,562	122,540	128,708	38,749	477,982
Japan	111,282	48,865	70,092	62,526	9,741	302,505

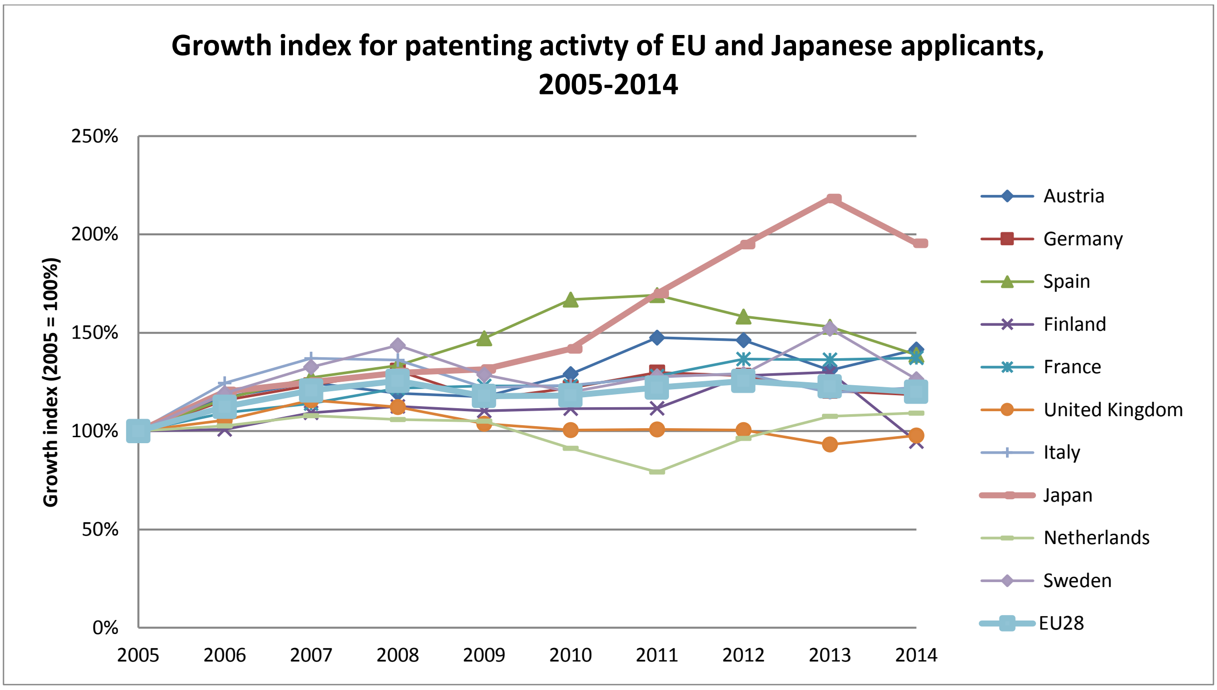
Source: EPO 2016

German applicants account for more than a third of all European patent applications and applicants in the three biggest European countries, Germany, France and the United Kingdom, are filing nearly two-thirds of all European patents and nearly as much as applicants from Japan. Contrary to their population size, countries like the Netherlands, Sweden and Finland are among the second tier countries with outputs similar to Spain or Italy. German applicants file most technologies in "mechanical engineering" (34%) and "chemistry" (25%).

Applicants from France and UK have most filings under the "chemistry section" (27% and 28% respectively) and both countries file around a quarter (26% and 24%) in section "electrical engineering". However, French applicants are filing around a quarter of all patents in the "mechanical engineering" section, where applicants from the UK only file 19% of their applications while UK applicants have a higher share (11%) of applications under section "other fields" than the European average (8%).

When looking at the development over time, it is observable that the Japanese output per year is increasing with higher dynamics than in most European countries and the EU as such. While Japanese applicants doubled their annual activity during 2005-2014 the EU28 countries only showed a growth rate of 20%. Within Europe, the dynamic varies considerably. Traditionally leading countries with an overall high patenting activity shower much smaller growth rates than the new member states in the East and South of the continent. While Germany (18%), France (37%), the Netherland (9%) or Sweden(26%) show moderate growth and the output of the UK (-2%) even shrank between 2005 and 2014, countries like Bulgaria, Cyprus, Estonia, Lithuania, Luxembourg, Malta, Poland, Portugal and Slovakia at least doubled their output during the period of observation.

Figure 2: Growth index for the development of the patenting activity of applicants from 10 European countries and Japan, 2005-2014



Source: EPO 2016

On the level of the technology fields, which represent a finer technological granularity, the regional differences become more apparent. In Japan, applicants file more than 10% in the field of "electrical machinery, apparatus, energy" around while European applicants have only 6% in this field. Japanese applicants file nearly three times as much patents for "semiconductors" than European ones. Japan also leads in the fields of "optics", "audio-visual technology" and to lesser extent in "computer technology".

European applicants, on the other hand, are leading in the fields of "digital communication", "medical technology", "organic fine chemistry", "pharmaceuticals", "transport", and "civil engineering". The only technology fields where the big three countries combined account for less than 50% of all European patents are "telecommunications", "digital communication", and "food chemistry".

Table 7: Number of patent applications from all European and Japanese applicants by technology section, 2005-2014

Technology Field	Japan	EU28	Germany	France	United Kingdom	Japanese share	EU28 share
Electrical machinery, apparatus, energy	32.683	30.456	15.075	3.641	2.565	10.80%	6.37%
Audio-visual technology	17.501	10.816	2.844	1.890	1.214	5.79%	2.26%
Telecommunications	8.172	10.768	2.131	1.811	1.333	2.70%	2.25%
Digital communication	10.060	25.051	3.903	4.409	2.620	3.33%	5.24%
Basic communication processes	2.930	3.360	1.045	567	372	0.97%	0.70%
Computer technology	17.760	21.439	5.188	3.816	3.514	5.87%	4.49%
IT methods for management	2.768	3.709	743	538	862	0.91%	0.78%
Semiconductors	19.408	9.824	4.628	1.516	833	6.42%	2.06%
Optics	16.756	8.992	3.327	1.401	1.081	5.54%	1.88%
Measurement	13.217	23.840	9.736	3.637	3.111	4.37%	4.99%
Analysis of biological materials	1.719	5.357	1.532	824	991	0.57%	1.12%
Control	4.153	7.595	3.033	972	1.025	1.37%	1.59%
Medical technology	13.020	26.780	8.238	3.031	4.001	4.30%	5.60%
Organic fine chemistry	7.628	18.903	6.928	3.923	2.555	2.52%	3.95%
Biotechnology	5.811	14.857	3.832	2.366	2.166	1.92%	3.11%
Pharmaceuticals	8.021	22.086	5.421	3.424	3.692	2.65%	4.62%
Macromolecular chemistry, polymers	9.649	9.669	4.357	1.316	521	3.19%	2.02%
Food chemistry	2.633	4.903	838	660	562	0.87%	1.03%
Basic materials chemistry	9.049	13.730	6.260	1.547	1.983	2.99%	2.87%
Materials, metallurgy	9.093	9.232	3.580	1.648	691	3.01%	1.93%
Surface technology, coating	7.884	7.047	3.114	1.046	627	2.61%	1.47%
Micro-structural and nano-technology	415	756	267	140	63	0.14%	0.16%
Chemical engineering	5.293	13.763	5.312	1.878	1.570	1.75%	2.88%
Environmental technology	4.615	7.594	2.708	1.217	841	1.53%	1.59%
Handling	5.791	15.411	4.905	1.819	1.661	1.91%	3.22%
Machine tools	6.836	11.976	6.134	1.215	757	2.26%	2.51%
Engines, pumps, turbines	9.412	20.123	10.302	2.971	1.691	3.11%	4.21%
Textile and paper machines	4.835	7.957	3.000	667	666	1.60%	1.66%
Other special machines	7.299	15.449	5.295	2.141	1.392	2.41%	3.23%
Thermal processes and apparatus	5.049	8.472	3.126	1.143	638	1.67%	1.77%
Mechanical elements	8.962	20.158	11.390	2.405	1.542	2.96%	4.22%
Transport	14.342	29.162	14.116	5.900	2.084	4.74%	6.10%
Furniture, games	3.280	10.729	2.774	1.143	1.877	1.08%	2.24%
Other consumer goods	3.543	10.790	3.699	1.477	1.566	1.17%	2.26%
Civil engineering	2.918	17.230	4.620	2.034	2.806	0.96%	3.60%

Source: EPO 2016

The development of patents filed per technology field per year varies among the fields and while considerable growth rates are observable for some of the technology fields it is apparent that some technologies are losing importance. Technology fields where the total number doubled at least during the period of observation are "electrical machinery, apparatus, energy", "IT methods for management", "thermal processes and apparatus" and "engines, pumps, turbines". Technology fields where the output in the year 2014 has been lower than in 2005 are: "audio-visual technology", "analysis of biological materials", "pharmaceuticals", "telecommunications", "organic fine chemistry" and "textile and paper machines".

Half of the patent applications from European and Japanese applications filed during the period of observation, where filed by individuals and institutional actors respectively. Around 73,000 different institutional applicants are recorded in PATSTAT. Institutional applicants mainly companies, universities, and governmental non-profit organisations account for 380,000 patents in Europe and Japan, whereas universities only account for around 14,000 patents or 3.6% of the total output.

Table 8: Applications from institutional applicants by sector in EU28 and Japan, 2005-2014

	Japan	EU28	Japan share	EU28 share
Company	160,070	194,339	95.94%	91.46%
Company gov non-profit	180	133	0.11%	0.06%
Company hospital	0	8	0.00%	0.00%
Company university	5	1	0.00%	0.00%
Gov non-profit	2,005	8,521	1.20%	4.01%
Gov non-profit hospital		1	0.00%	0.00%
Gov non-profit university	10	48	0.01%	0.02%
Hospital	30	222	0.02%	0.10%
University	4,532	9,207	2.72%	4.33%
Total	166,845	212,493		

Source: EPO 2016

While the share individual applicants have on the total output, is higher in Europe (54% vs. 44%) the distribution among institutional actors does not vary considerably. The only difference is that the sector of governmental NPOs is more important in the European context where around 4% of all institutional applicants come from this sector. This situation, however, is mainly due to the situation France where 44% of this sector's applicants are based. These French actors include institutions like "Institut National De La Recherche Agronomique" (INRA), "Institut Curie" or "Centre National De La Recherche Scientique" (CNRS). However, the university sector plays an important role in the technology fields "analysis of biological materials" (share of 23% of all applications), "biotechnology" (22%), "pharmaceuticals" (16%) and "micro-structural and nano-technology" (14%).

Ownership of EU-Japan co-inventions

In the context of analysing the cooperation the cooperation pattern between Europe and Japan, the overall performance of the knowledge production systems is interesting, but the important question of who are the applicants of jointly developed knowledge is, of course, more important. Therefore, the overall output of the regions has been filtered that only applications with at least one European and one Japanese inventors are considered.

The following table illustrates the numbers of co-inventions, which got jointly developed by European and Japanese inventors and are filed by applicants in one of the covered countries during the period 2005-2014. The share of these applications that got filed by a Japanese institution or person is about 46%. Looking at the overall patent distribution between applicants in these two regions, this share is slightly higher than expected, which indicates that these patents are more likely to be filed by Japanese actors.

When looking at the results on country level, it becomes clear that the concentration of applicants on the three big European countries, Germany, United Kingdom and France is even higher for co-inventions with Japan then it is for the overall patenting activity. These three countries account for more than three-quarters of all applicants filing these co-inventions. There are six EU countries that do not have any actor filing these co-inventions at all. Technology-wise, more than 40% of the co-inventions fall into the "chemistry" section, which means that this section is far more important for both region's applicants filing co-inventions than it is compared to the overall patenting activity. The share of patents in the "electrical engineering" section is about 10% higher in Europe for co-inventions and a little bit lower for Japan. This indicates that European actors profit from the collaborative knowledge generation with Japanese partners, a region that has a high specialisation on these technologies.

Table 9: Applications of co-inventions between EU and Japan by applicant 's country and technology section, 2005-2014

	Electrical engineering	Instruments	Chemistry	Mechanical engineering	Other fields	Total
Austria	5.8	0.8	4.4	0.6	-	11.7
Belgium	13.2	8.8	30.6	5.7	0.7	59.0
Bulgaria	0.2	0.1	-	-	-	0.3
Czech Republic	1.1	0.3	0.7	0.1	-	2.2
Germany	130.1	37.7	245.0	62.2	5.4	480.4
Denmark	5.5	1.0	23.7	1.2	-	31.3
Spain	1.4	0.9	8.6	0.1	0.5	11.5
Finland	78.5	1.3	1.6	3.0	-	84.4
France	20.2	15.8	95.7	37.2	9.1	178.0
United Kingdom	79.6	13.6	67.1	27.2	9.5	197.0
Greece	-	1.1	1.0	0.1	-	2.2
Croatia	0.4	-	-	-	-	0.4
Hungary	1.9	2.0	1.9	1.6	-	7.4
Ireland	1.8	0.4	0.8	0.4	-	3.4
Italy	3.0	2.2	13.6	3.5	3.0	25.3
Luxembourg	2.1	0.3	0.5	-	-	2.9
Netherlands	9.1	7.5	24.9	8.7	4.7	54.9
Poland	2.7	-	2.4	-	-	5.1
Portugal	-	-	0.8	-	-	0.8
Romania	0.8	-	-	0.2	-	0.9
Sweden	52.4	5.0	10.3	4.3	0.2	72.2
Slovenia	-	-	0.9	-	-	0.9
EU28	409.7	98.9	534.3	156.2	33.0	1,232.1
Japan	332.8	103.5	419.6	153.3	26.8	1,036.0

Source: EPO 2016

On the level of a higher technological granularity, the results for the applicants filing co-inventions jointly developed between European and Japanese inventors reveal differences to the overall activity of these actors. The share of Japanese applicants is considerably lower in the fields of "electrical machinery, apparatus, energy", "audio-visual technology", "semiconductors" and "optics" while the share of European applicants is lower in the fields of "medical technology" and "mechanical elements". On the other hand, technology fields where the share of co-inventions is notably higher than for other applications, are "digital communication", "organic fine chemistry", "macromolecular chemistry, polymers" and "basic materials chemistry" for both European and Japanese applicants. Additionally, Japanese applicants file more patents in the field "pharmaceuticals" if European inventors are involved in the patent's development.

The legal status of the institutional applicants does not vary between the overall activity and the one limited to co-inventions. The vast majority of applicants are companies (92%). Other types of institutions are universities and government owned NPOs. When looking at the applicants in detail, the following particulars can be extracted.

Table 10: Number of filed co-inventions from all European and Japanese applicants by technology section, 2005-2014

Technology Field	Japan	EU28	Germany	France	United Kingdom	Japanese share	EU28 share
Electrical machinery, apparatus, energy	55.8	70.2	38.7	6.8	12.5	5.39%	5.70%
Audio-visual technology	16.2	22.3	4.1	2.2	2.5	1.56%	1.81%
Telecommunications	29.7	36.0	7.8	1.8	4.8	2.87%	2.92%
Digital communication	144.8	175.9	49.8	3.4	33.3	13.98%	14.28%
Basic communication processes	2.4	5.4	2.3	0.6	2.1	0.23%	0.44%
Computer technology	39.3	42.5	7.7	2.3	10.4	3.79%	3.45%
IT methods for management	7.8	10.3	1.0	-	3.0	0.76%	0.84%
Semiconductors	36.8	47.1	18.7	3.1	11.0	3.55%	3.82%
Optics	23.8	24.2	10.1	4.7	2.5	2.30%	1.97%
Measurement	36.5	42.7	13.4	8.7	8.1	3.52%	3.47%
Analysis of biological materials	11.3	9.1	2.4	1.2	1.8	1.09%	0.74%
Control	8.2	5.5	2.3	0.1	0.4	0.79%	0.45%
Medical technology	23.7	17.3	9.5	1.1	0.8	2.29%	1.40%
Organic fine chemistry	90.0	133.5	66.9	42.3	11.3	8.69%	10.83%
Biotechnology	37.1	53.2	12.0	3.8	4.9	3.58%	4.32%
Pharmaceuticals	68.2	59.5	19.1	8.8	15.8	6.59%	4.83%
Macromolecular chemistry, polymers	66.5	63.0	27.7	13.8	5.0	6.42%	5.11%
Food chemistry	8.8	14.8	1.3	2.0	2.4	0.85%	1.20%
Basic materials chemistry	54.4	107.0	75.4	8.5	11.0	5.25%	8.68%
Materials, metallurgy	26.6	28.9	11.6	4.0	4.6	2.56%	2.35%
Surface technology, coating	20.4	26.8	12.4	5.0	3.9	1.97%	2.18%
Micro-structural and nano-technology	1.0	0.8	0.7	0.1	0.0	0.09%	0.07%
Chemical engineering	30.1	32.6	14.4	5.6	5.1	2.91%	2.64%
Environmental technology	16.6	14.2	3.4	1.9	2.9	1.60%	1.15%
Handling	10.8	8.7	0.6	0.6	2.9	1.04%	0.71%
Machine tools	10.4	8.8	2.0	2.8	1.8	1.00%	0.72%
Engines, pumps, turbines	43.0	28.0	8.8	2.9	13.9	4.15%	2.27%
Textile and paper machines	9.2	6.5	3.7	0.0	1.7	0.88%	0.53%
Other special machines	19.0	21.0	6.9	4.6	2.8	1.83%	1.71%
Thermal processes and apparatus	13.9	9.8	3.3	1.9	0.1	1.34%	0.79%
Mechanical elements	18.5	18.1	9.6	4.3	2.0	1.78%	1.47%
Transport	28.5	55.2	27.4	20.1	2.0	2.75%	4.48%
Furniture, games	3.4	4.1	0.7	0.5	1.7	0.33%	0.34%
Other consumer goods	11.2	14.9	2.3	3.4	5.3	1.08%	1.21%
Civil engineering	12.2	14.0	2.3	5.2	2.5	1.17%	1.14%

Source: EPO 2016

When looking at the applicants filing co-inventions of European and Japanese inventors the following is observable. A total of 795 institutional applicants filed patents which have been developed in EU-Japan collaboration. In this context, it is important to state that individuals have been filtered out of this data as we are focusing only on institutions active in these processes. However, the applicant share has been calculated including all natural and legal persons attributing each entity the same share as we do not have any information on actual ownership structures. One can assume that institutions will own a higher share than inventors but without any information on contractual details any adjustments would be based on speculation. Even between two legal entities the ownership of patents might vary from case to case. Therefore, the applicant share as displayed in Table 11 might under-represent the actual ownerships. Responding to this difficulty, not only the shares have been calculated but also the number of applications is depicted.

In total 2,540 patent applications have been developed with the involvement of at least one European and Japanese inventors. From these 2,268 patents have been filed by applicants registered either in the EU or Japan and around 840 can be attributed to institutional applicants. The database contains

795 institutional applicants filing these patents, thus one applicant on average files 1.1 applications which are a result of this interregional cooperation. From these institutional applicants a little less than half (364) are registered in Japan. It has to be stated that the data retrieved from PATSTAT has not manipulated to unify different branches from the same multinational corporation (e.g. patents for "Nokia Corporation" and "Nokia Solutions and Networks" have not been summarised under "Nokia").

Table 11: Top-20 institutions filing most EU-Japan co-inventions, 2005-2014

No.	Institution's Name	Institution's country	Applicant share of patents	Number of patents with involvement
1	BASF (Badische Anilin & Soda Fabrik)	Germany	36.4	82
2	Telefonaktiebolaget LM Ericsson	Sweden	23.5	81
3	Panasonic Corporation	Japan	23.1	83
4	Nokia Corporation	Finland	21.9	100
5	NEC Corporation	Japan	21.7	66
6	NTT Docomo	Japan	19.8	45
7	Sumitomo Chemical Company	Japan	17.0	34
8	L'Oreal	France	16.4	42
9	Bayer Cropscience	Germany	14.4	115
10	Compagnie Generale des Etablissements Michelin	France	13.8	38
11	Novozymes	Denmark	12.8	31
12	Mitsubishi Heavy Industries	Japan	12.3	36
13	Robert Bosch	Germany	10.4	39
14	Merck Patent	Germany	9.7	39
15	Nokia Siemens Networks	Finland	9.1	31
16	Toyota Motor Corporation	Japan	8.8	54
17	Sony Corporation	Japan	8.4	32
18	IBIDEN Company	Japan	8.2	29
19	DSM IP Assets (Dutch State Mines IP Assets)	Netherlands	7.5	44
20	Kaneka Corporation	Japan	7.3	11

Source: EPO 2016

The Top-20 institutional applicants account for a little more than a third (302) of all applications and are all companies. Nine of these corporations are based in Japan, four in Germany, two in Finland and France, and one in Sweden, Denmark and the Netherlands respectively. These corporations account for shares between 7 and 36 patent applications per company but at the same time have been involved in the development of 11 to 115 patent applications. This discrepancy highlights that patents shares and ownership should not be used synonymously. Analysing the single applicants according to the technology of their applications would go beyond the scope of this study as for example, the BASF applications alone are attributed to 13 different technology fields.

In this subchapter, we described the patent activity of inventors and applicants in Europe and Japan. We identified the countries and technologies with the highest outputs as well as actors driving the cooperation between these two regions. We saw that the overall cooperation between the regions is rather low compared to the overall output of the R&D systems of the covered countries. The total numbers are useful for understanding the overall situation but to recognise the specialisation of the innovation systems, we need another kind of analyses.

2.2 Specialisation patterns in patenting

In this subchapter, we analyse the specialisation patterns based on the patent applications discussed in the previous one. First, we look at inventor data including co-inventions before the level of applicants is scrutinised. The RTA index is used to identify specialisation advantages whereby vales above one indicate a relative specialisation. The analysis again is based on technology sections and the finer granularity of technology fields.

2.2.1 Specialisation of inventive activity

Upon looking at the RTA analysis conducted on country level for the overall patent activity of the inventors per broader technology sections, we can conclude that “electrical engineering” is dominated by Japan, while only a few European countries have specialisation advantages, such as Finland, Sweden and Romania. The majority of the EU28 member states are rather specialised in other fields or the “chemistry” section where Belgium, the Czech Republic, Denmark, Spain, Croatia, Hungary, Latvia, Poland, Portugal and Slovenia show specialisation advantages although some of them with a relatively low overall patent number. In contrast, Japan shows a specialisation advantage in “electrical engineering” and a clear disadvantage in “other fields” where these European countries are specialised. Among the European countries with the top 3 patent output, Germany has a specialisation advantage in “mechanical engineering” and a specialisation disadvantage in “electrical engineering”, the United Kingdom has a slight disadvantage in “mechanical engineering” and an advantage in the other fields, while France shows no particular specialisation patterns on the technology section level. If we take into account the overall patent number and the RTA-index, a clear specialisation is visible in case of “electrical engineering” for Finland and Sweden, in the case of “instruments” for Ireland, in the case of “chemistry” for Belgium. Austria can be considered as having a specialisation in “other fields.”

If we analyse the RTA-indices on the level of the 35 narrower technology fields, a more detailed conclusions can be drawn concerning specialisation patterns of certain countries. Japanese inventors have a clear specialisation advantage in the field of “semiconductors” with a RTA index of 1.75, the country's highest specialisation in all the technology fields. This is a relatively high value since European countries with similar patent output have similar top RTA-index values: Germany’s highest value of 1.68 is in technology field “mechanical elements”, France’s highest value of 1.59 is in technology field “organic fine chemistry” while the United Kingdom’s highest value of 1.85 is in technology field “analysis of biological materials”.

Japan has further specialisation advantages in the fields “audio-visual technology” (1.56), “optics” (1.70), “macromolecular chemistry, polymers” (1.32) and “surface technology, coating” (1.39). Germany has a clear specialisation advantage in “machine tools” (1.43), “engines, pumps, turbines” (1.47), “mechanical elements” (1.68) and “transport” (1.41). France has a clear specialisation advantage in “organic fine chemistry” (1.59) and “transport” (1.56) – France can be considered the least specialised country among the top 3 patenting EU member states. The United Kingdom has a clear specialisation advantage in “IT methods for management” (1.83), “analysis of biological materials” (1.85), “pharmaceutical” (1.59), “furniture, games” (1.73) and “civil engineering” (1.84) – the latter two explains the specialisation in the section "other fields". A table with the RTA indices for all 29 countries and 35 technology fields can be found in the annex.

Table 12: RTA index for inventors on country level and technology sections, 2005-2014

	RTA for "electrical engineering"	RTA for "instruments"	RTA for "chemistry"	RTA for "mechanical engineering"	RTA for "other fields"
Austria	0.79	0.84	0.87	1.24	1.90
Belgium	0.70	0.78	1.63	0.81	1.12
Bulgaria	0.89	0.70	0.79	1.20	2.33
Cyprus	0.59	1.12	1.17	0.84	2.45
Czech Republic	0.59	0.82	1.33	1.10	1.53
Germany	0.75	0.96	0.98	1.32	1.02
Denmark	0.63	1.11	1.31	0.95	1.35
Estonia	1.22	1.24	1.16	0.53	0.62
Spain	0.58	0.88	1.27	1.00	2.08
Finland	1.80	0.62	0.63	0.78	0.74
France	0.85	0.91	1.11	1.10	1.05
United Kingdom	0.89	1.20	1.07	0.75	1.70
Greece	0.65	0.82	1.17	1.15	1.71
Croatia	0.54	0.80	1.38	0.92	2.35
Hungary	1.08	0.76	1.27	0.75	1.13
Ireland	1.14	1.68	0.80	0.58	1.18
Italy	0.50	0.85	1.00	1.32	2.33
Japan	1.25	1.04	0.97	0.85	0.52
Lithuania	0.59	1.21	1.24	0.81	2.08
Luxembourg	0.62	0.76	0.99	1.58	1.00
Latvia	0.44	0.77	1.91	0.76	1.34
Malta	1.10	0.42	0.87	1.04	2.38
Netherlands	1.07	1.33	1.04	0.66	1.06
Poland	0.73	0.77	1.34	0.91	1.74
Portugal	0.62	0.95	1.40	0.83	1.88
Romania	1.35	0.88	0.57	0.97	1.55
Sweden	1.42	0.91	0.63	0.96	1.06
Slovenia	0.51	0.66	1.43	0.75	3.30
Slovakia	0.85	0.54	0.95	1.35	1.64

RTA values highlighted if below 0.75 (red) or above 1.25 (green)
Source: EPO 2016

There are some outliers with high RTA-indices in the case of smaller countries due to their overall low patent output. Taking into consideration this caveat, we can still confirm that specialisation patterns exist in smaller countries. For instance, high specialisation in the "digital communication" technology is observable in Finland (5.28) and Sweden (4.10) and both countries are also specialised in "telecommunication" as well (2.87 and 2.67 respectively). The Netherlands has specialisation advantages in "audio-visual technology" (1.68) and "food chemistry" (3.83). Italy is specialised in other fields, such as "furniture, games" (2.47) and "other consumer goods" (2.82). Spain has a specialisation advantage in "micro-structural and nanotechnology" and "pharmaceuticals" (2.27). In "pharmaceuticals" also Belgium and Italy can be considered specialised (1.63 and 1.57 respectively), with the former further having a high RTA-index in "biotechnology" (2.19), "macromolecular chemistry, polymers" (2.21) and "food chemistry" (2.11). Austria has the highest RTA-index in technology field "transport" (2.26).

2.2.2 Specialisation of the institutional knowledge base

After analysing the specialisation of European countries and Japan based on the inventive activity of people living three, we now focus on the specialisation measured by applicants of these countries. First, the level of technology sections is scrutinised before studying the specialisation patterns with higher technological granularity on the level of the technology fields.

Looking at the results for the RTA analyses on country level for the overall patent activity of the applicants located there, a few things are apparent. The section "electrical engineering" is dominated by Japanese applicants, the high output and therefore the clear specialisation is only challenged by Finland and Sweden. These small countries clearly profit from hosting world leading multinationals in the field of telecommunications. On the other hand, most European countries are specialised on technologies in "other fields", which encompasses "furniture and games", "other consumer goods" and "civil engineering". It is noteworthy that, most of the countries with an overall high patent activity show no or only a minor specialisation in this section. Japan shows a clear specialisation disadvantage in this section. In the section "instruments", the especially the specialisation of the Netherlands and Ireland are noteworthy while other countries also show specialisation on these technologies but have a rather weak overall patent activity (e.g. Malta), leading to extreme results of the RTA index. The Japanese RTA index for this section is also slightly above unity, indicating a light specialisation. High specialisation values and a high patenting activity for section "chemistry" can be observed in Belgium, Denmark and Spain but also the big three European countries Germany, France and United Kingdome show specialisation indices between 1 and 1.12 indicating that their high output in this section is also connected with a specialisation advantage. In the "mechanical engineering" section Italian and German applicants combine a high output with a clear specialisation, to a lesser extent this also true for Austrian applicants.

Table 13: RTA index for applicants on country level and technology sections, 2005-2014

	RTA for "electrical engineering"	RTA for "instruments"	RTA for "chemistry"	RTA for "mechanical engineering"	RTA for "other fields"
Austria	0.73	0.79	0.95	1.24	2.04
Belgium	0.56	0.79	1.73	0.82	1.38
Bulgaria	0.80	0.66	0.83	1.28	2.37
Cyprus	0.63	0.83	1.25	0.91	2.50
Czech Republic	0.47	0.80	1.45	1.15	1.57
Germany	0.71	0.96	1.00	1.37	1.03
Denmark	0.53	1.11	1.39	0.99	1.40
Estonia	0.99	1.37	1.24	0.60	0.71
Spain	0.52	0.91	1.32	1.01	2.13
Finland	1.80	0.58	0.63	0.77	0.70
France	0.89	0.90	1.11	1.06	1.07
United Kingdom	0.83	1.18	1.12	0.77	1.81
Greece	0.51	0.83	1.20	1.29	1.79
Croatia	0.50	0.81	1.38	0.95	2.48
Hungary	0.84	0.87	1.42	0.77	1.30
Ireland	0.94	1.62	1.00	0.59	1.32
Italy	0.45	0.87	1.03	1.38	2.31
Japan	1.27	1.04	0.94	0.84	0.52
Lithuania	0.52	1.25	1.30	0.84	2.03
Luxembourg	0.72	1.17	0.94	1.15	1.53
Latvia	0.42	0.79	1.89	0.81	1.41
Malta	0.41	2.54	0.94	0.61	1.65
Netherlands	1.05	1.34	1.08	0.61	1.14
Poland	0.57	0.81	1.46	0.94	1.92
Portugal	0.57	0.97	1.45	0.83	2.00
Romania	1.16	1.03	0.68	0.90	1.83
Sweden	1.46	0.85	0.58	0.95	1.07
Slovenia	0.48	0.67	1.55	0.78	2.95
Slovakia	0.77	0.60	0.94	1.40	1.76

RTA values highlighted if below 0.75 (red) or above 1.25 (green), Source: EPO 2016

On the level of the technology fields, representing a higher technological granularity, these general results can be analysed with greater detail. A table with the RTA indices for all 29 countries and 35 technology fields can be found in the annex. The most outstanding result probably is the specialisation of Japanese applicants on semiconductor technology with a RTA index of 1.71, the country's highest specialisation in one of the technology fields. The only European country with a value above one in this field is Luxembourg, however with a low total output. Other technology fields with a high specialisation of Japanese applicants are "optics" (1.68), "electrical machinery, apparatus, energy" (1.34), "surface technology, coating" (1.36) and "macromolecular chemistry, polymers" (1.29).

Selected results, based on the total patent activity, for European countries, illustrate the following picture. German applicants have specialisation advantages in the fields "mechanical elements" (1.76), "engines, pumps, turbines" (1.57), "machine tools" (1.47), "transport" (1.46). French applicants are specialised in technologies for "organic fine chemistry" (1.65), "transport" (1.51), "digital communication" (1.40) and "micro-structural and nano-technology" (1.34). Applicants registered in the UK show advantages in technologies for "analysis of biological materials" (1.97), "civil engineering" (1.96), "IT methods for management" (1.87), "pharmaceuticals" (1.73), "biotechnology" (1.47) and "medical technology" (1.41).

Additionally, specialisations in "telecommunications" technology is observable in Finland (2.86) and Sweden (2.91) and both countries are also specialised in "digital communication" (5.34 and 4.67 respectively). Finland, in addition, is also showing advantages in "computer technology" (2.23) and "IT methods for management" (1.83). Specialisations on "analysis of biological materials" can be discovered in Spain (1.82), Belgium (1.71) and Denmark (1.67). High levels of specialisation on "biotechnology" are apparent in Denmark (3.53), Belgium (2.45), Spain (2.10), Netherlands (1.45), UK (1.47), France (1.27) and Austria (1.17) and with the exception of the Netherlands these countries also have advantages in "pharmaceutics". In the important field of "transport" technologies France (1.51) and Germany (1.46) show high advantages and Sweden (1.13) to some extent while Japan (0.85) has no advantage in "transport" technology.

In the previous two sections, the patenting activity of European countries and Japan has been described and the specialisation of their specialisation has been analysed. The gained insights are crucial for the interpretation of the following analysis of knowledge flows between these two regions.

2.3 International knowledge flows and networks

Highly specialised knowledge is a rare and spatially concentrated. Thus, accessing international hotspots of knowledge creation and learning from involved actors is vital for the economic success of actors relying on developments made abroad. In the following chapter, the international flow of knowledge is analysed in two different ways. On the one hand, international networks of collaborative knowledge generation, in the form of co-invention networks, and on the other hand international knowledge flows from inventors to applicants are investigated. Co-invention networks are important because they represent international collaboration in the inventive process and may give inventors insights to specialised knowledge in foreign countries. The ownership flows, in most cases illustrate the research activities of multinational companies, who strategically decide to tap in a country's knowledge base to gain access to specialised knowledge they might not be able to acquire at home.

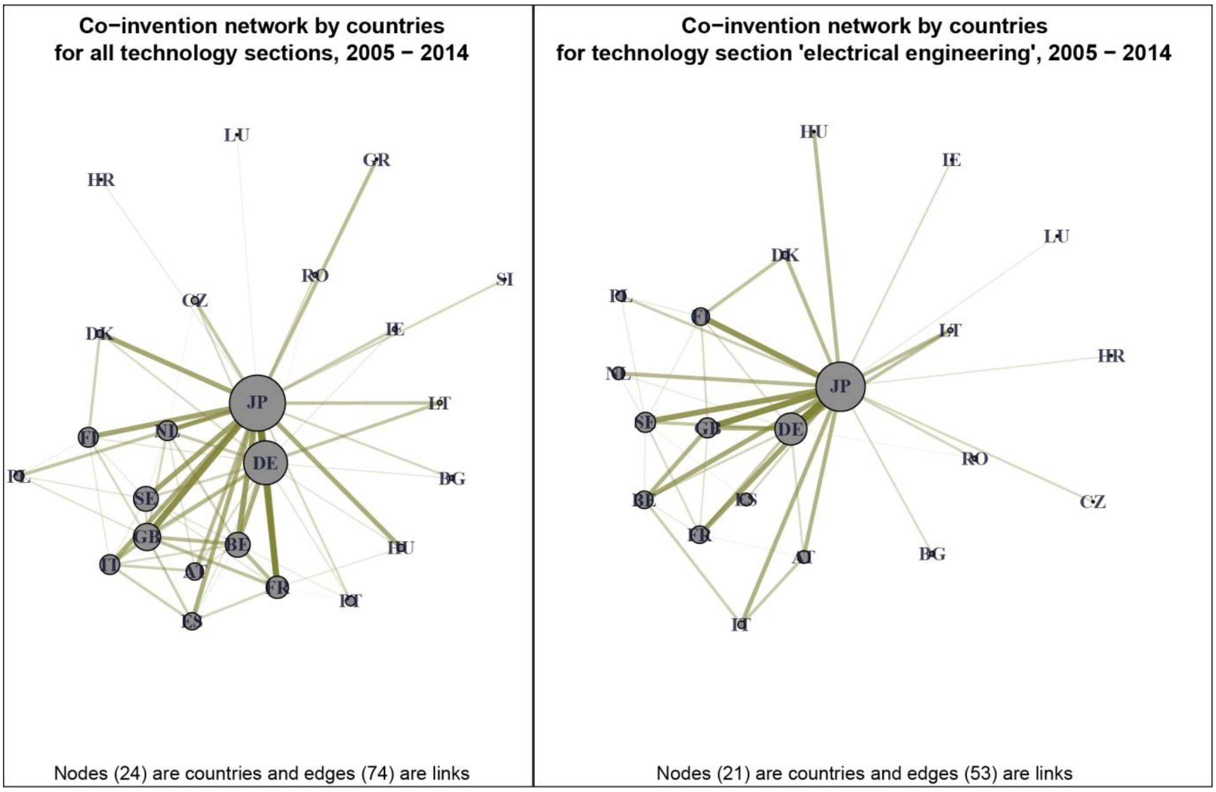
2.3.1 International co-invention networks

The international co-invention network between EU and Japan is analysed taking only patents into account where at least one European and one Japanese inventor are involved. Thus, co-inventions between two different European inventors are only considered if a third inventor from Japan has also been collaborating. Omitting most of the intra-European cooperation has the disadvantage of only considering a small section of the actual cooperation patterns for the European countries. But at the same time, the cooperation between Europe and Japan is our main interest and focusing on this small sample leads to a more targeted analysis with a clearer picture of the knowledge flows between these two regions. The scale difference between the covered countries and this targeted sample, results in networks that are dominated by Japan and to some extent by Germany. The networks put these two countries in the centre and are close to star networks.

The SNA for these co-inventions is only conducted on the level of technology sections as the overall sample is small and therefore the results on the level of the technology fields would be of limited interpretative value. In contrast to previous sections, patents are not counted fractional for the SNA. The attributed value for each link between two countries has the value one because the number of involved inventors is seen not as relevant. Nevertheless, the networks are weighted by the number of observed interactions.

The overall network, including all co-inventions, consists for 24 country-nodes that are connected by 74 edges. The most central countries are Japan and Germany. The strongest ties are observable for the country pairs Japan-Germany, Japan-United Kingdom, Japan-France, Japan-Finland and Japan-Netherlands. Strong triadic relationships are present for cooperation including Japan-Germany-France, Japan-Germany-United Kingdom and Japan-France-United Kingdom. It is noteworthy, that this very specific network including only EU-Japan cooperation, shows the highest density between the West European countries. Many of the Eastern and Southern EU countries do have links with Japan but these cases do not include partners from other European countries leading to single edges between these countries and Japan, leaving those countries at the network's fringe. The centrality measures for this overall network reveal the following structures. Due to the selection of patents, Japan is the most central actor with a (normalised) degree and eigenvector centrality of one. Germany is clearly the most important European partner country of Japan in this network with a degree centrality of 0.78. The close ties with Japan also lead to an eigenvector centrality of 0.93. Other countries with high degree centralities are United Kingdom (0.48), Sweden and Belgium (0.43 each). These centralities are a result of a dense component of Western European countries that even in this specific network have multiple ties with each other. The eigenvector centrality, which indicates if existing links are with other important nodes within the network, shows the highest levels, not considering Japan and Germany, for France (0.36), United Kingdom (0.31) and Belgium (0.12). While the first two both have strong ties with Japan (and Germany), later is interesting as Belgium is well connected with all big countries.

Figure 3: Visualisation of co-invention networks for overall network and for technology section "electrical engineering"



Node size based on degree
Source: EPO 2016

As the networks for the single technology sections are subsets of the above-described network, they show similar patterns. The network for the "electrical engineering" technology section is the biggest subset for co-inventions between Europe and Japan and consists of 21 country nodes that are connected by 53 edges. Again, Japan and Germany are the most central actors and a Western European component is visible in the network. Other countries with strong ties to Japan are France, United Kingdom, Sweden and Finland. Japan, as in all other networks, has a degree and eigenvector centrality of one. Other countries with a high degree, and therefore many connections with the network, are Germany (0.65), Sweden (0.40), United Kingdom (0.40), France (0.35), Finland (0.35) and Belgium (0.35). The highest eigenvector centralities are observable for Germany (0.87), United Kingdom (0.42), Finland (0.22) and Sweden (0.20).

The network for the section "instruments" is smaller, only containing 17 country nodes that are connected by 28 edges. Because Germany is not as central as in previously described networks, the network's structure is closer to an actual star graph with only one central node (Japan). Even though a small Western European component is still visible, the connections between European countries are much weaker in this network. The strongest ties are once again visible between Japan-Germany, Japan-France, Japan-United Kingdom and to a lesser extend between Japan-Belgium and Japan-Netherlands. The countries with the highest degree centrality are Germany (0.48), France (0.32), Belgium (0.31), United Kingdom (0.25) and Austria (0.19). The highest eigenvector centrality is visible for Germany (0.86), France (0.34), United Kingdom (0.26), Sweden (0.16) and Belgium (0.13).

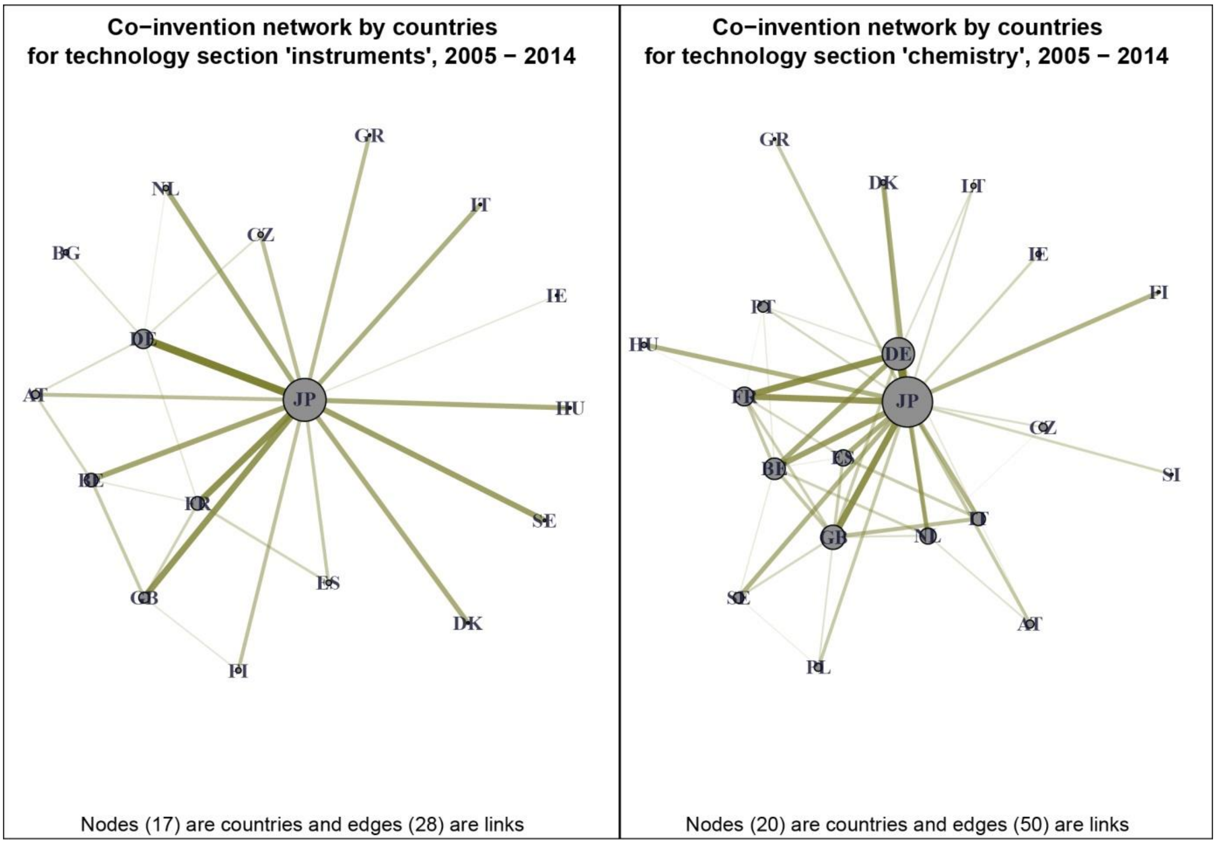
Table 14: Network centralities for section co-invention networks on country level, 2005-2014

	Electrical engineering		Instruments		Chemistry		Mechanical engineering		Other technologies		All sections	
Country	DC	EC	DC	EC	DC	EC	DC	EC	DC	EC	DC	EC
Austria	0.25	0.04	0.19	0.04	0.16	0.00	0.11	0.02	-	-	0.30	0.01
Belgium	0.35	0.09	0.31	0.13	0.42	0.12	0.17	0.08	0.25	0.11	0.43	0.12
Bulgaria	0.10	0.00	0.13	0.01	-	-	0.06	0.00	-	-	0.09	0.00
Cyprus	-	-	-	-	-	-	-	-	-	-	-	-
Czech Republic	0.05	0.00	0.13	0.04	0.16	0.00	0.11	0.00	-	-	0.13	0.00
Germany	0.65	0.87	0.44	0.86	0.63	0.98	0.50	0.84	0.13	0.26	0.78	0.93
Denmark	0.15	0.03	0.06	0.09	0.11	0.04	0.06	0.00	-	-	0.13	0.04
Estonia	-	-	-	-	-	-	-	-	-	-	-	-
Spain	0.25	0.00	0.13	0.02	0.32	0.03	0.11	0.01	0.13	0.01	0.30	0.03
Finland	0.35	0.22	0.13	0.03	0.05	0.02	0.17	0.05	-	-	0.35	0.05
France	0.35	0.11	0.31	0.34	0.37	0.41	0.28	0.35	0.38	0.78	0.39	0.36
United Kingdom	0.40	0.42	0.25	0.26	0.47	0.25	0.22	0.42	0.38	0.58	0.48	0.31
Greece	-	-	0.06	0.04	0.05	0.00	0.06	0.00	-	-	0.04	0.01
Croatia	0.05	0.00	-	-	-	-	-	-	-	-	0.04	0.00
Hungary	0.05	0.02	0.06	0.09	0.11	0.02	0.17	0.02	-	-	0.13	0.03
Ireland	0.05	0.00	0.06	0.00	0.11	0.00	0.11	0.00	-	-	0.09	0.00
Italy	0.15	0.04	0.06	0.07	0.26	0.02	0.22	0.03	0.25	0.17	0.35	0.03
Lithuania	0.10	0.03	-	-	0.11	0.00	-	-	-	-	0.09	0.01
Luxembourg	0.05	0.00	-	-	-	-	-	-	-	-	0.04	0.00
Latvia	-	-	-	-	-	-	-	-	-	-	-	-
Malta	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	0.25	0.03	0.13	0.10	0.32	0.03	0.17	0.09	0.13	0.07	0.35	0.04
Poland	0.20	0.01	-	-	0.16	0.00	0.06	0.00	-	-	0.17	0.00
Portugal	-	-	-	-	0.21	0.00	-	-	-	-	0.17	0.00
Romania	0.10	0.01	-	-	-	-	0.06	0.00	-	-	-	-
Sweden	0.40	0.20	0.06	0.16	0.21	0.02	0.17	0.03	0.13	0.01	-	-
Slovenia	-	-	-	-	0.05	0.00	-	-	-	-	-	-
Slovakia	-	-	-	-	-	-	-	-	-	-	-	-
Japan	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

DC: normalised degree centrality; EC: eigenvector centrality
Source: EPO 2016

The "chemistry" network contains 20 country nodes that are connected by 50 edges. It shows similarities to the overall network with Japan and Germany as the two central actors and a Western European component. Strongest ties again exist between Japan and the big three European countries. The European countries with most ties and therefore the highest degree centrality are Germany (0.63), United Kingdom (0.47), Belgium (0.42), France (0.36), Spain (0.32) and the Netherland (0.32). The eigenvector centrality shows that Germany (0.98) is nearly as important as Japan in a network that is skewed towards Japan. The close ties of France with the two central actors lead to an eigenvector centrality of 0.41. While the eigenvector centralities for the United Kingdom (0.25) and Belgium (0.12) are much lower.

Figure 4: Visualisation of co-invention networks for technology sections "instruments" and "chemistry"

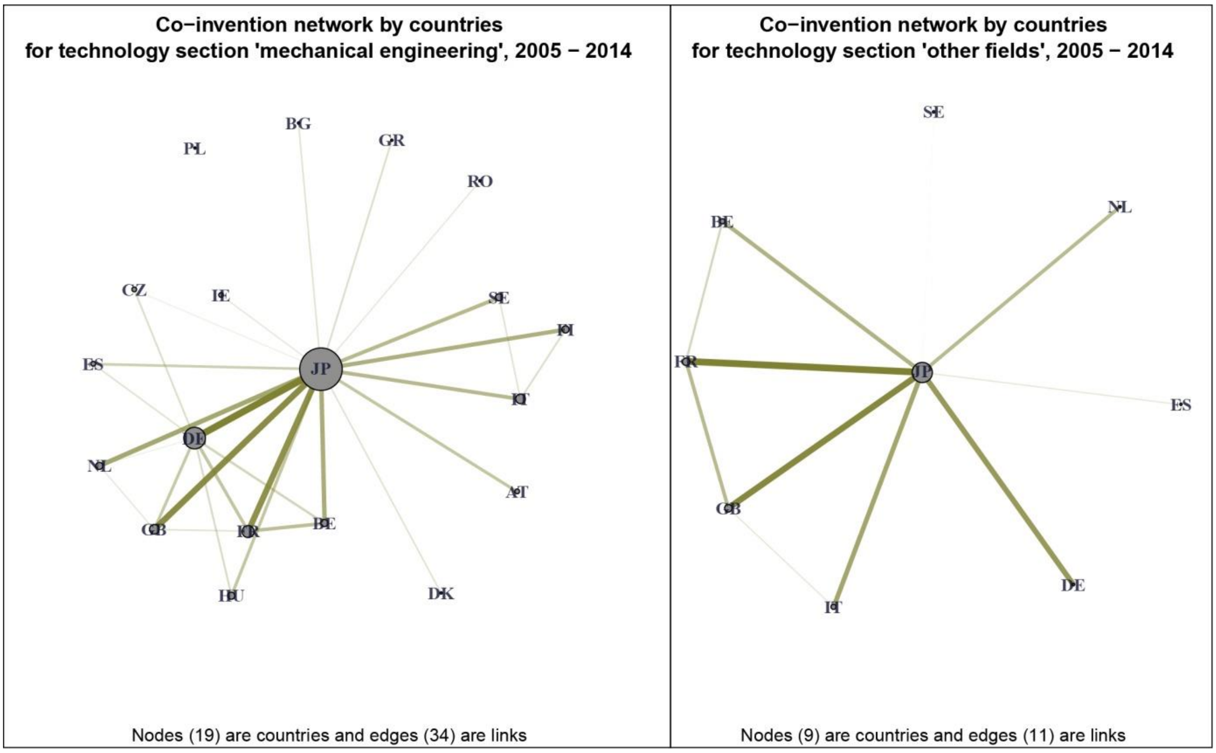


Node size based on degree
Source: EPO 2016

The "mechanical engineering" section network consists of 19 country nodes and 34 edges. The structure is close to a star graph with Japan as central actor. Besides the three big European countries, the Netherlands show a strong tie to Japan. Again, these countries have the highest degree centralities in the network but the overall values are lower compared to other sections - the degree centralities for these countries are Germany (0.50), France (0.28), Italy (0.22) and United Kingdom (0.22). The highest eigenvector centralities are observable for Germany (0.84), United Kingdom (0.42) and France (0.35).

The network for "other technologies" is by far the smallest, consisting only of nine country nodes that are connected by eleven edges. This network of all sections is the one closest to a star graph. The most important ties are Japan-France and Japan-United Kingdom. The highest degree centralities exists for France (0.38), United Kingdom (0.38), Italy (0.25) and Belgium (0.25). The eigenvector centralities are highest for France (0.78), United Kingdom (0.58) and Germany (0.26).

Figure 5: Visualisation of co-invention networks for technology sections "mechanical engineering" and "other fields"



Node size based on degree
Source: EPO 2016

All these networks reveal the importance of the big three European countries (Germany, France and United Kingdom) in international co-patenting, which of course to some extent is based on scale effects. But the central positions of countries like Sweden (electrical engineering), Finland (electrical engineering) or Belgium (chemistry, instruments) in some of the networks indicate specialisations in these technologies. Before summarising the results of the previous sections, the last analysis on knowledge flows and foreign ownership is conducted in the following section.

2.3.2 Foreign ownership flows

The second kind of knowledge flows we are going to scrutinise are cases of foreign ownership. Foreign ownership is defined as applicants from one country filing patents developed by inventors in another country. These patents, therefore, represent a knowledge flow from the inventor's country to the applicant's country. A typical case for these flows is a research location, where the new knowledge is generated, owned by a multinational enterprise who files the patent in its home country, where the headquarter is located. This type of arrangement can be either intra-firm or inter-institutional. Both cases represent a form of foreign direct investment with a focus on R&D. The applicant can tap into a foreign knowledge base and profit from the specialised environment and therefore reduce the costs of developing or acquiring this knowledge at home.

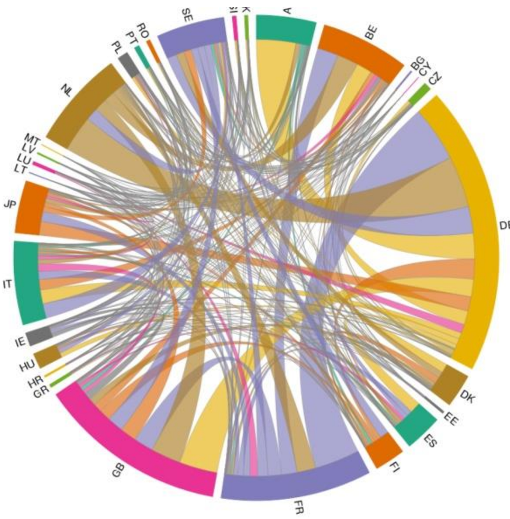
In this section, we are analysing the international knowledge flows on country and technology section level. In contrast to the inventor networks, we again count the patents fractionally, allowing for a more detailed analysis. Another difference is, that in this section we take all international flows between the covered countries into account and not only co-inventions with European and Japanese inventors. Thus, inner-European flows are covered as well. A patent is defined as internationally owned if at least one inventor is from another country as one of the applicants. Having the ownership structure analysed in section 2.1.2 in mind, we know that many inventors are also mentioned as applicants. Thus, only the portion of a patent that has a foreign applicant is counted while the share attributed to persons does not represent a knowledge flow. The only way to mitigate this inaccuracy would again be to filter individuals (co)-filing patents out, but as we do not have any information on the contractual situation regarding individual patents, this would simply substitute one skew with another. For the interpretation of the following results it is, therefore, important to have in mind that the actual flow of knowledge and economic value might be higher than depicted. The analysis mainly focuses on the balance between in- and outflows. A positive net balance indicates that a country “imports” more patents invented abroad than it “exports” patents invented locally.

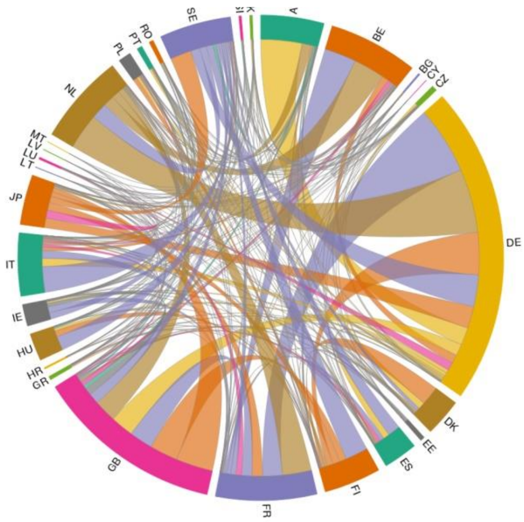
In total the following analysis is based on some 39,000 patents developed and filed in 29 countries. Third countries that might also be involved in these patents, are filtered out on inventor and applicant level thus only cases of cross-border flows between the countries in this study are subject of the analysis. The countries with the highest difference between in- and outflows of patents are the Netherlands (2,128), Sweden (1,882), Finland (1,077) and Luxembourg (1,034). It is noteworthy, that these countries are rather small with a strong industrial and knowledge base but are only to some extent among the countries with the highest total activity. Even when looking on the total inflow, the Netherlands are second only after Germany, and Sweden is experiencing a higher inflow than France or the United Kingdom. Small countries with a limited knowledge base, that profit from a higher in- than outflow are Luxembourg, Ireland (334), Malta (129) and Cyprus (108). It can be hypothesised that these flows are the result of the present taxation policies in these countries that potentially attracts headquarters or branches managing the firms intellectual property (e.g. licensing within a corporate group).

Japan has a small (294) plus of inflows from European countries with total inflows of 1,907 and outflows of 1,612. Compared to inner-European knowledge flows this innovative country only plays a minor role. The main targets for outflows from Japan are Germany (475), France (333), Sweden (177), United Kingdom (148), the Netherlands (142) and Luxembourg (97). On the other hand, Japan is attracting knowledge developed in the United Kingdom (567), Germany (488), France (230), Sweden (249), Finland (98) and Italy (77).

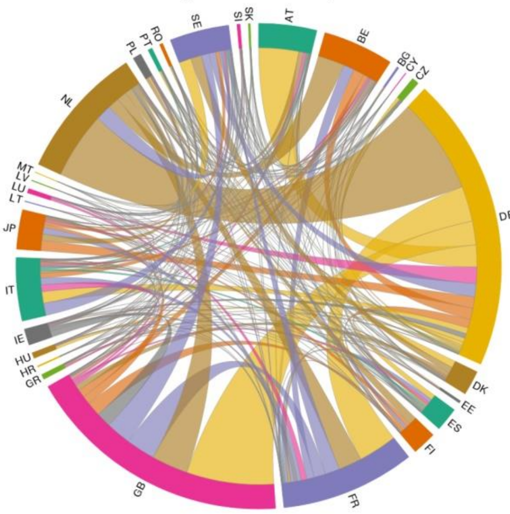
On the disaggregated level of technology section, the following flows are observable. The countries with the highest difference between in- and outflow for technology section "electrical engineering" are Sweden (plus 956), the Netherlands (921), Finland (721), France (676) and Japan (584). Most important countries as a source for new knowledge flowing out are Germany (-2,904), United Kingdom (-1,715), France (-921), the Netherlands (-827) and Belgium (-815). Japan is experiencing an inflow of 1,039 and an outflow of 456 patents. The outflow of Japanese patent applications in this section is mainly filed by applicants from Germany (98), Luxembourg (81), Finland (78) and Sweden (64). Foreign ownership by Japanese applicants in most often present for inventors from United Kingdom (376), Germany (221), Sweden (213) and France (106).

Figure 6: Knowledge flows between Europe and Japan as measured by foreign ownership, 2005-2014
For an interactive version of these diagrams, visit bibliometrics.zsi.at/studies/vis/JEUPISTE

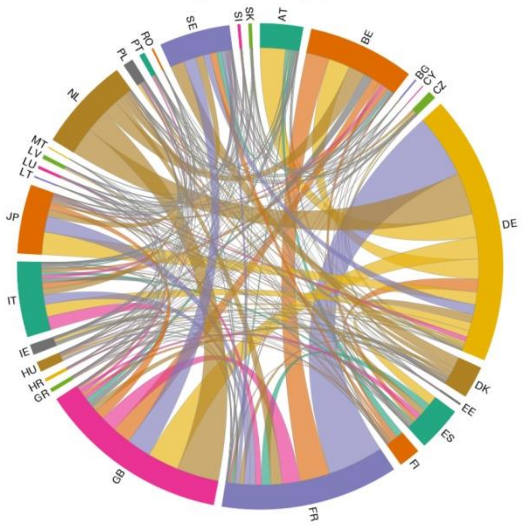




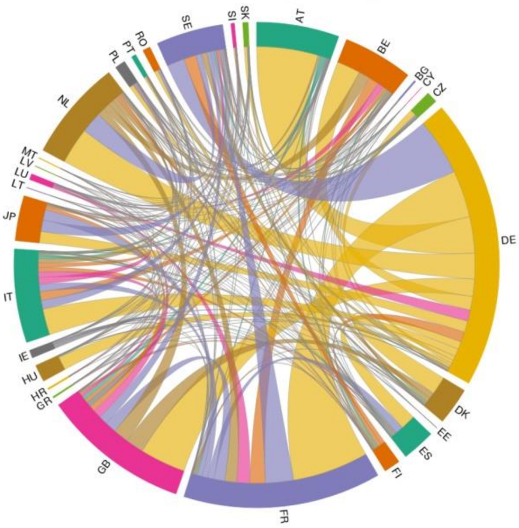
Knowledge flows from inventor to applicant country for section „instruments“, 2005-2014



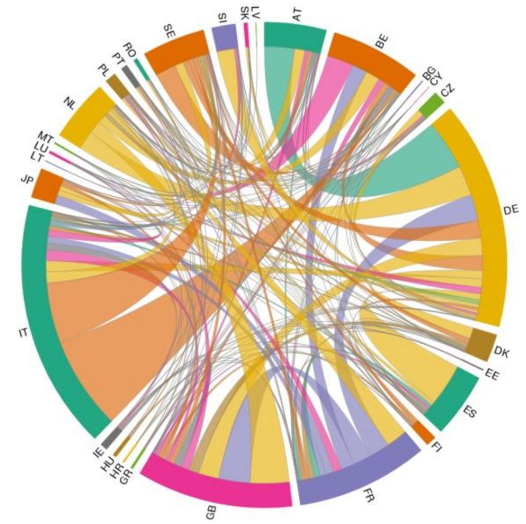
Knowledge flows from inventor to applicant country for section „chemistry“, 2005-2014



Knowledge flows from inventor to applicant country for section „mechanical engineering“, 2005-2014



Knowledge flows from inventor to applicant country for section „other fields“, 2005-2014



The countries with the highest net-balance under the "instruments" section are the Netherlands (405), Sweden (189), Germany (165), Luxembourg (128), Ireland (74) and Malta (65). Countries with considerable outflows are United Kingdom (-655) and Italy (-154). Japan has a positive balance of about 10 patents with overall low numbers (inflow 163, outflow 153) in this section, thus neither Japanese nor European applicants rely on knowledge developed in the other region. Applicants filing Japanese inventions in this section are mainly based in Germany (45), the Netherland (28) and France (27). The inflow's sources are Germany (49), United Kingdom (36) and Finland (17).

Under the "chemistry" section the highest net-balance is apparent for the Netherlands (686), Luxembourg (225), Ireland (217), Denmark (151), Finland (144) and Austria (114). Negative knowledge flow balances are observable for United Kingdom (-539), Italy (-426), Japan (-235) and Spain (-105). Interestingly, the countries with the highest inflows at the same time also experience high outflows with rather balanced ratios - with the exceptions of the Netherlands and United Kingdom. The Japanese outflows are filed by German (244), French (171), Dutch (76) and British (62) applicants in most cases. European inventions filed by Japanese applicants are most often from Germany (134), United Kingdom (110), France (62), Belgium (33) or Italy (27).

In the "mechanical engineering" section the highest net balances are visible for Germany (764), Sweden (619), Luxembourg (304) and Finland (161) while the lowest ones are apparent for France (-461), United Kingdom (-451), Italy (-406) and Austria (-150). Japan also has a negative net balance in this section with 52 more patents flowing out than in the country. But again, the cooperation base for these flows in rather low with an inflow of 229 and an outflow of 281 patents. The outflow of Japanese patents in mainly filed by applicants in Germany (80), Sweden (79) and France (72) while inventions from European inventors filed by Japanese applicants are developed in Germany (78), United Kingdom (40), France (34) and Italy (31).

The "other technologies" section is the smallest section. Countries with a high net balance between in- and outflows are the Netherlands (177), Belgium (144), Luxembourg (114) and Sweden (102). Countries with high negative balances are Italy (347), United Kingdom (101) and Spain (74). The Japanese balance is slightly negative (12) with an outflow of 51 and inflow of 39 patents. The outflow is mainly filed by French (17) and Dutch (11) applicants while the inflow's origin is France (15), Italy (8) or Germany (6).

The analysis of knowledge flows as measured by foreign-owned patents shows that Japan is owning more European developed applications than the other way round. However, the knowledge flows exist in both directions and depend on the field. At the same time these flows are on an average mostly inner-European. Given the size of Japan and its role in global knowledge production, there is definitely room for deepening the collaboration in patenting activity. After analysing the total activity, the specialisation and international knowledge flows in this chapter, we now will synthesise the main findings and draw conclusions from it.

3. Summarising the main findings

The aim of this report is to give an overview about collaboration between Europe and Japan in R&D measured by patenting activities. While patents are the most important indication of inventive activity and novel codified knowledge it is important to keep the limitations of this indicator in mind (see chapter 1.2.1). We analysed the patenting activity to illustrate the overall activity, dynamics, specialisation and collaboration of 29 countries (EU28 plus Japan) during the time frame 2005-2014 in the different technology sections and fields. The applied methodology encompasses methods of Revealed Technological Advantage analysis and Social Network Analysis. In this chapter, we summarise the results of the analyses in chapter 2 before drawing conclusions. The summary is collecting the most important results from previous analyses on the level of technology sections. Please refer to chapter 2 for results with a finer technological granularity.

The technology section "electrical engineering" constitutes the main component of Japan's knowledge base with a high patenting activity and specialisation advantage that is only met by a few European countries. Japanese inventors developed more than 97,000 patents in this section and an RTA value of 1,27 indicates a clear specialisation advantage. Japan’s specialisation in this section is mainly due to the specialisation in the fields "semiconductor" and "audio-visual technologies". European inventors were involved in the development of nearly 115,000 patents. While German inventors - like in all sections - produce the highest amount of patents among European countries, the country does not show a specialisation advantage in this section and only a minor one in the technology field "electrical machinery, apparatus, energy". Among the other European countries, especially Sweden and Finland have a high output combined with clear specialisation advantages in this section. The specialisation of the Nordic countries is rooted in advantages in technologies for "digital communication" and "telecommunications". Finland is additionally specialised in "computer technologies" and "IT methods for management".

When looking at knowledge flows in this section it is also apparent that the countries that show specialisation advantages further profit from a positive knowledge flow balance, hence the outflows of locally developed knowledge in smaller than the inflow of knowledge developed by inventors abroad. The countries with the highest net-balance are Sweden (positive inflow of 956 and a RTA of 1.46), Finland (721 and 1.80), the Netherlands (921 and 1.05) as well as Japan (854 and 1.27). Countries like these, which have a strong knowledge base and specialisation advantages, seem to profit even more from incoming international knowledge flows than others. This most likely is caused by leading companies investing in R&D at home and abroad, where they are able to tap into a knowledge base with different technological foci, therefore potentially reducing the costs of developing the knowledge locally or of acquiring this knowledge at their home country. When looking at the co-inventions of European and Japanese inventors, this finding is confirmed to some extent. While most co-inventions are developed in a collaborative process between colleagues from Japan, Germany or the United Kingdom, results that mirror the size of these countries, the Nordic countries are the third and fourth most important European cooperation partner country for Japanese inventors. This is also reflected in the rather high centralities these countries have in the EU-Japan co-invention network. However, it has to be emphasised that the overall cooperation between these two regions is low. Less than 800 patent applications were the result of cooperation between European and Japanese inventors in this section.

Table 15: Main indicators for technology section "electrical engineering" on country level, 2005-2014

	Patent activity (inventor level)	Knowledge flow (balance)	Specialisation (RTA - inventor level)	Co-inventions with Japan/EU	Degree centrality	Eigenvector centrality
Austria	2,846	-272	0.73	8.70	0.25	0.04
Belgium	2,330	-476	0.56	14.26	0.35	0.09
Bulgaria	87	-5	0.80	0.92	0.10	-
Cyprus	16	20	0.63	-	-	-
Czech Republic	302	-34	0.47	1.05	0.05	-
Germany	36,732	-982	0.71	154.40	0.65	0.87
Denmark	2,076	-207	0.53	8.22	0.15	0.03
Estonia	114	-24	0.99	-	-	-
Spain	2,599	-212	0.52	1.62	0.25	-
Finland	7,838	721	1.80	64.81	0.35	0.22
France	16,677	676	0.89	21.74	0.35	0.11
United Kingdom	14,785	-1,090	0.83	101.09	0.40	0.42
Greece	182	-21	0.51	-	-	-
Croatia	79	-8	0.50	0.50	0.05	-
Hungary	688	-200	0.84	3.28	0.05	0.02
Ireland	1,182	-4	0.94	2.08	0.05	-
Italy	4,376	-464	0.45	5.52	0.15	0.04
Lithuania	34	-2	0.52	0.20	0.10	0.03
Luxembourg	89	264	0.72	1.17	0.05	-
Latvia	27	-1	0.42	-	-	-
Malta	8	10	0.41	-	-	-
Netherlands	9,285	921	1.05	6.30	0.25	0.03
Poland	475	-75	0.57	3.53	0.20	0.01
Portugal	209	-19	0.57	-	-	-
Romania	175	-26	1.16	1.33	0.10	0.01
Sweden	11,334	956	1.46	42.76	0.40	0.20
Slovenia	176	-14	0.48	-	-	-
Slovakia	105	-14	0.77	-	-	-
Japan	97,382	584	1.27	337.71	1.00	1.00

Source: EPO 2016

The technology section "instruments" is smaller than "electrical engineering" with a total of 45,000 Japanese and nearly 74,000 European patent applications. Like in all sections, the vast majority of European patents is developed by inventors based in one of the three big European countries, namely Germany, United Kingdom and France. Countries with a specialisation in this section include the Netherlands (RTA 1.34), United Kingdom (1.18), Denmark (1.11) and to a lesser extent Japan (1.04). On a finer level of technological granularity, the Japanese specialisation is especially notable in "optics" technology (1.70). The Netherlands show a specialisation in "medical technology" (1.64), the "analysis of biological materials" (1.39) and "optics" (1.29). The United Kingdom and Denmark show specialisation in "analysis of biological materials" (1.85 UK, 1.53 DK) and "medical technology" (1.45 UK, 1.88 DK).

The countries mainly profiting from international knowledge flows in the "instruments" section are the Netherlands, Sweden, Germany and Luxembourg. The latter is an interesting case: Its domestic knowledge base is small - also as a result of its overall size - but the country is able to profit from international flows. Japan has balanced in- and outflows in this section. The link between specialisation and the positive knowledge flow balance is only visible for some countries under the instruments section. While the Netherlands have the highest specialisation advantage (based on an above average activity) and a positive inflow, this is not the case for the United Kingdom, which is experiencing a negative balance. Denmark has a slightly positive flow balance. The share of co-inventions of European and Japanese inventors is small in this section as well - only a little more than 210 co-inventions are recorded. Most of these collaborative patents are developed by Japan-based inventors in cooperation with colleagues from Germany, the United Kingdom and France. These are therefore also the most central actors in the co-invention network. However, small countries like Belgium, Sweden and the Netherlands also have fairly central positions within this network.

Table 16: Main indicators for technology section "instruments" on country level, 2005-2014

	Patent activity (inventor level)	Knowledge flow (balance)	Specialisation (RTA - inventor level)	Co-inventions with Japan/EU	Degree centrality	Eigenvector centrality
Austria	1,680	-87	0.79	1.79	0.19	0.04
Belgium	1,464	-66	0.79	9.58	0.31	0.13
Bulgaria	39	-3	0.66	0.17	0.13	0.01
Cyprus	17	10	0.83	-	-	-
Czech Republic	235	-10	0.80	0.36	0.13	0.04
Germany	26,310	165	0.96	39.02	0.44	0.86
Denmark	2,041	26	1.11	1.01	0.06	0.09
Estonia	65	-4	1.37	-	-	-
Spain	2,190	-27	0.91	0.87	0.13	0.02
Finland	1,514	41	0.58	1.05	0.13	0.03
France	10,006	-58	0.90	13.18	0.31	0.34
United Kingdom	11,133	-655	1.18	16.97	0.25	0.26
Greece	129	-12	0.83	1.57	0.06	0.04
Croatia	66	-2	0.81	-	-	-
Hungary	271	-11	0.87	2.62	0.06	0.09
Ireland	978	74	1.62	0.50	0.06	-
Italy	4,130	-154	0.87	3.31	0.06	0.07
Lithuania	45	1	1.25	-	-	-
Luxembourg	61	128	1.17	-	-	-
Latvia	25	-1	0.79	-	-	-
Malta	-	65	-	-	-	-
Netherlands	6,427	405	1.34	5.50	0.13	0.10
Poland	281	-11	0.81	-	-	-
Portugal	179	-4	0.97	-	-	-
Romania	63	-6	1.03	-	-	-
Sweden	4,052	189	0.85	5.39	0.06	0.16
Slovenia	128	-3	0.67	-	-	-
Slovakia	38	1	0.60	-	-	-
Japan	45,203	10	1.04	107.62	1.00	1.00

Source: EPO 2016

Under the "chemistry" section the European Union patenting activity is much higher than the Japanese one. While Japanese inventors developed around 68,000 patents, their European colleagues are responsible for more than 124,000 applications. The highest outputs in the EU are again observable in Germany, the United Kingdom and France. Besides the big three, the Netherlands, Italy, Spain, Sweden and Belgium have high patenting activity in this section. The highest specialisation advantages, combined high patenting activity, are apparent in Belgium (RTA 1.73), Denmark (1.39) and Spain (1.32). Specialisations without a high output exist in the Czech Republic (1.45), Slovenia (1.55), Poland (1.46) and Portugal (1.45). Smaller advantages by an overall high activity are also notable for the United Kingdom (1.12) and France (1.11), this is particularly relevant as big countries tend to have smaller specialisation indices. At the finer technological granularity of technology fields, the following results are especially interesting. In Japan, specialisation advantages exist in technologies of "micro-structural and nano-technology" (1.82), "environmental technology" (1.48) and "organic fine chemistry" (1.39).

From the highly specialised European countries, the most relevant aspects are that Belgium shows a specialisation in "macromolecular chemistry, polymers" (2.21), "biotechnology" (2.19) and "food chemistry" (2.11) and smaller advantages in nearly all fields of the section. The Danish specialisation is in technologies for “biotechnology" (3.25), "food chemistry" (3.07) and "pharmaceuticals" (2.19). Spain has high specialisation advantages in "micro-structural and nano-technology" (2.47), "pharmaceuticals" (2.27) and in "food chemistry" (2.12). The big countries France and the United Kingdom have advantages in "organic fine chemistry" (UK 1.33, FR 1.59), "biotechnology" (UK 1.26, FR 1.37) and "pharmaceuticals" (UK 1.59, FR 1.28).

The countries that profit most from international knowledge in this section are the Netherlands, Luxembourg, Ireland, Finland and Denmark. With the exception of Denmark, these are not the countries with the highest specialisation advantage in this section. Japan and especially the United Kingdom are facing a negative flow balance. With a little less than 1,000 co-inventions developed in collaboration between European and Japanese inventors, the share of bilateral co-patenting is small also in this section. Apart from Germany, France and the United Kingdom the cooperation with Belgium, the Netherlands and Italy is noteworthy. These countries also have the highest centralities in the co-invention network.

Table 17: Main indicators for technology section "chemistry" on country level, 2005-2014

	Patent activity (inventor level)	Knowledge flow (balance)	Specialisation (RTA - inventor level)	Co-inventions with Japan/EU	Degree centrality	Eigenvector centrality
Austria	2,818	114	0.95	4.64	0.16	-
Belgium	4,911	56	1.73	34.41	0.42	0.12
Bulgaria	70	-2	0.83	-	-	-
Cyprus	27	30	1.25	-	-	-
Czech Republic	614	-20	1.45	0.71	0.16	-
Germany	43,434	-73	1.00	234.99	0.63	0.98
Denmark	3,899	151	1.39	15.46	0.11	0.04
Estonia	95	-7	1.24	-	-	-
Spain	5,104	-105	1.32	11.23	0.32	0.03
Finland	2,495	144	0.63	2.45	0.05	0.02
France	19,521	-75	1.11	89.02	0.37	0.41
United Kingdom	15,972	-539	1.12	78.20	0.47	0.25
Greece	296	-14	1.20	1.19	0.05	-
Croatia	183	-16	1.38	-	-	-
Hungary	728	-61	1.42	2.84	0.11	0.02
Ireland	744	217	1.00	0.83	0.11	-
Italy	7,856	-426	1.03	15.74	0.26	0.02
Lithuania	74	-1	1.30	0.10	0.11	-
Luxembourg	125	225	0.94	-	-	-
Latvia	117	-11	1.89	-	-	-
Malta	8	28	0.94	-	-	-
Netherlands	8,095	686	1.08	16.11	0.32	0.03
Poland	787	-50	1.46	4.33	0.16	-
Portugal	426	-12	1.45	0.99	0.21	-
Romania	64	-8	0.68	-	-	-
Sweden	4,510	17	0.58	8.94	0.21	0.02
Slovenia	444	-0	1.55	0.85	0.05	-
Slovakia	106	-12	0.94	-	-	-
Japan	67,922	-235	0.94	449.91	1.00	1.00

Source: EPO 2016

In the section "mechanical engineering" Japanese inventors developed more than 59,000 and European ones 130,000 patents. The difference in the number of patents between the regions is the biggest in this section. German inventors developed nearly as many patents as their Japanese colleagues. Additionally, French, British and Italian based persons show high levels of activity too. Furthermore, the very high output in this section, dominated by these countries, is not entirely surprising as the section contains the technology field "transport", which is one of the biggest fields of all. However, it might be rather unexpected that Japan does neither have a specialisation advantage in this section as such (0.84) nor a single field of the section, including the field "transport" (0.86). This might be the case because many, especially big, European countries do have a high output in this field. Japan also has very high outputs in other fields, which affects the specialisation index.

Table 18: Main indicators for technology section "mechanical engineering" on country level, 2005-2014

	Patent activity (inventor level)	Knowledge flow (balance)	Specialisation (RTA - inventor level)	Co-inventions with Japan/EU	Degree centrality	Eigenvector centrality
Austria	3,969	-150	1.24	0.65	0.11	0.02
Belgium	2,414	-57	0.82	6.09	0.17	0.08
Bulgaria	107	-2	1.28	0.17	0.06	-
Cyprus	15	23	0.91	-	-	-
Czech Republic	506	-34	1.15	0.64	0.11	-
Germany	58,061	764	1.37	62.94	0.50	0.84
Denmark	2,800	55	0.99	0.63	0.06	-
Estonia	42	2	0.60	-	-	-
Spain	3,975	-83	1.01	0.10	0.11	0.01
Finland	3,050	161	0.77	2.55	0.17	0.05
France	19,203	-461	1.06	38.23	0.28	0.35
United Kingdom	11,190	-451	0.77	36.18	0.22	0.42
Greece	287	-3	1.29	0.35	0.06	-
Croatia	121	-5	0.95	-	-	-
Hungary	429	-80	0.77	2.87	0.17	0.02
Ireland	537	14	0.59	0.20	0.11	-
Italy	10,311	-406	1.38	3.86	0.22	0.03
Lithuania	48	1	0.84	-	-	-
Luxembourg	201	304	1.15	-	-	-
Latvia	45	-2	0.81	-	-	-
Malta	6	13	0.61	-	-	-
Netherlands	5,154	-60	0.61	9.71	0.17	0.09
Poland	529	-38	0.94	0.08	0.06	-
Portugal	250	-12	0.83	-	-	-
Romania	112	-40	0.90	0.25	0.06	-
Sweden	6,853	619	0.95	5.04	0.17	0.03
Slovenia	231	-7	0.78	-	-	-
Slovakia	150	-14	1.40	-	-	-
Japan	59,467	-52	0.84	154.18	1.00	1.00

Source: EPO 2016

The European countries with the highest the highest level of specialisation and a reasonable output in “mechanical engineering” are Italy (1.38), Germany (1.37), Austria (1.24) and France (1.04). High specialisations with a low patenting activity are apparent for Slovakia (1.40), Bulgaria (1.28) and the Czech Republic (1.15). Italian specialisation in this section is based on the fields "handling" technologies (2.59), "thermal processes and apparatus" (1.79) and "other special machines" (1.61). German inventors have advantages in all the fields of the section but especially in "mechanical elements" (1.68), "engines, pumps, turbines" (1.48), "machine tools" (1.43) and "transport" (1.42). Austria shows a specialisation in "machine tools" (1.77), "handling" (1.57) and in "textile and paper machines" (1.52).

French inventors are most specialised in "transport" (1.56) and "engines, pumps, turbines" (1.14). Countries that have the highest positive net balance (i.e. that import more patents invented abroad than they “export”) for knowledge flows in this section are Germany, Sweden, Luxembourg and Finland while the countries with the highest outflow are France, United Kingdom and Italy. Japan too, has a higher outflow than inflow of knowledge under this section.

The number of co-inventions between European and Japanese inventors is especially small in this section with just 325 joint patents. Most important collaboration links once again involve Japan and the big three European countries, namely Germany, France and United Kingdom. Beside these patterns, the cooperation between Japan, the Netherlands and Belgium play a minor role. These countries therefore also take central positions in the collaboration network and have rather high centrality measures.

Table 19: Main indicators for technology section "other fields" on country level, 2005-2014

	Patent activity (inventor level)	Knowledge flow (balance)	Specialisation (RTA - inventor level)	Co-inventions with Japan/EU	Degree centrality	Eigenvector centrality
Austria	1,535	-264	2.04	-	-	-
Belgium	839	-113	1.38	0.83	0.25	0.11
Bulgaria	52	-1	2.37	-	-	-
Cyprus	15	-6	2.50	-	-	-
Czech Republic	176	-14	1.57	-	-	-
Germany	11,255	837	1.03	5.19	0.13	0.26
Denmark	1,006	-95	1.40	-	-	-
Estonia	13	9	0.71	-	-	-
Spain	2,084	22	2.13	0.75	0.13	0.01
Finland	726	17	0.70	-	-	-
France	4,645	-386	1.07	8.90	0.38	0.78
United Kingdom	6,354	88	1.81	11.15	0.38	0.58
Greece	108	11	1.79	-	-	-
Croatia	78	10	2.48	-	-	-
Hungary	162	-19	1.30	-	-	-
Ireland	275	-203	1.32	-	-	-
Italy	4,584	20	2.31	3.76	0.25	0.17
Lithuania	31	2	2.03	-	-	-
Luxembourg	29	78	1.53	-	-	-
Latvia	21	10	1.41	-	-	-
Malta	8	-14	1.65	-	-	-
Netherlands	2,080	-746	1.14	1.41	0.13	0.07
Poland	255	13	1.92	-	-	-
Portugal	143	-1	2.00	-	-	-
Romania	45	-32	1.83	-	-	-
Sweden	1,904	602	1.07	0.17	0.13	0.01
Slovenia	257	-6	2.95	-	-	-
Slovakia	46	-1	1.76	-	-	-
Japan	9,131	183	0.52	34.30	1.00	1.00

Source: EPO 2016

The "other fields" section is the smallest of the five sections consisting only of three fields, "furniture, games", "other consumer goods" and "civil engineering". It shows the lowest patenting activity with around 9,100 Japanese and 39,000 European patents. Germany alone has more patents in this section than Japan. Besides the big three European countries, Italy, Spain, the Netherlands, Sweden and Austria have a considerable number of patents in this section. While Japan (0.52) is facing a remarkable specialisation disadvantage in this section, most European countries have high specialisation indices.

This situation is at least to some extent due to the small overall output in this section (which increases specialisation indices). However, the countries with specialisation advantages and a high activity in this section are Italy (2.31), Spain (2.13), Austria (2.04) and the United Kingdom (1.81). These countries all have specialisation advantages in all three fields. The highest values are observable for "other consumer goods" in Italy (2.83), "civil engineering" in Spain (2.25), Austria (2.26) and United Kingdom (1.85). The knowledge flows between inventor and applicant country have the highest net balance in Germany, Sweden and Japan (ie. these countries are importing knowledge) while countries with considerable outflows are the Netherlands, France, Austria and Ireland. This is particularly interesting because the Netherlands and Ireland are among the countries with the highest net balance of knowledge flows over all sections.

The number co-inventions jointly developed between European and Japanese inventors are particularly low in this section. As little as 66 patents have been the result of this kind of collaboration. The majority of these patents are the outcome of Japanese and British or French cooperation. Only eight European countries have co-inventions with Japan in this section. This reflects the overall low activity and specialisation of Japanese inventors in this section.

However, due to the limitations of patent applications as innovation indicator, the result's implications in regard to policy recommendation should be approached with greatest caution and deliberation. Patents are just one among several possible outputs of research collaboration and they represent economic value in some cases, sometimes they only make strategic sense or the other way round – relevant inventions are not filed at all. For policy, the interesting question is whether and how the collaborative patents can be exploited and literature shows that, this varies from application to application. What this analysis shows are sectors and actors with relevant knowledge and specialisation advantages and that the cooperation between those is rather limited. However, Japan is known as a country with a less internationalised and collaborative knowledge production.

Intensified cooperation between specialised partners could be mutual beneficial but what the study cannot show, is if existing collaboration takes place on intra-firm (different locations of the same multinational) level or if the observed collaboration is on the inter-firm or inter-institutional level. If it is a policy goal to push open innovation in an international fashion, co-inventions can be a useful indicator for innovation in some sectors.

4. Bibliography

Archibugi, D. and Pianta, M. (1996): Measuring Technological Change through patents and innovation surveys, in: *Technovation*, 16(9), 451-468.

Balassa, B. (1965): Trade liberalisation and "revealed" comparative advantage. *The Manchester School 33*(2), 99-123

Bas, C.L. and Sierra, C. (2002): 'Location versus home country advantages' in R&D activities: Some further results on multinationals' locational strategies. *Research Policy 31*(4), 589-609

Bonacich, P. (1987): Power and centrality: A family of measures. *American Journal of Sociology 92*(5), 1170-1182

Brandes, U. and Erlebach, T. (2005): *Network Analysis - Methodological Foandations*. Berlin, Heidelberg and New York, Springer

Breschi, S. and Lissoni, F. (2004): Knowledge spillovers and local innovation systems: A critical survey*. Industrial and Corporate Change 10*(4), 975-1005

Carrington, P.J., Scott, J. and Wasserman, S. (2005): *Models and methods in social network analysis.* New York, Cambridge University Press

Constantelou, A., Tsakanikas, A. and Caloghirou, Y. (2004): Inter-country technological linkages in European Framework Programmes: A spur to European integration? *International Journal of Technology Management 27*(8), 773-790

De Prato, G. and Nepelski, D. (2012): Global R&D network. A network analysis of international R&D centres (No. JRC79478).

Dernis, H. and Guellec, D. (2001): Using patent counts for cross-country comparisons of technology output, OECD, Paris. Online available at: http://www.oecd.org/sti/inno/21682515.pdf

Faust, K. (1997): Centrality in affiliation networks. *Social Networks 19*(2), 157-191

Giuri, P. et al. (2007): Inventors and invention processes in Europe: Results from the PatVal-EU survey, in: *Research Policy*, 36, 1107-1127.

Griliches, Z. (1990): Patent Statistics as Economic Indicators: A Survey, in: *Journal of Economic Literature*, 28, 1661-1707.

Guellec, D. and van Pottelsberghe de la Potterie, B. (2001): The internationalisation of technology analysed with patent data, in: *Research Policy*, 30, 1253-1266.

Hagedoorn, J. (2003): Sharing intellectual property rights – an exploratory study of joint patenting amongst companies, in: *Industrial and Corporate Change*, 12(5), 1035-1050.

Heller-Schuh, B., Barber, M., Henriques, L., Paier, M., Pontikakis, D., Scherngell, T., Veltri, G.A. and Weber, M. (2011): Analysis of networks in European framework programmes (1984-2006). Luxembourg

Meyer, M. (2006): Academic Inventiveness and Entrepreneurship: On the Importance of Start-Up Companies in Commercializing Academic Patents, in: *Journal of Technology Transfer*, 31, 501-510.

Maggioni, M.A., Nosvelli, M. and Uberti, T.E. (2007): Space versus networks in the geography of innovation: A European analysis. *Papers in Regional Science 86*(3), 471-493

Nagaoka, S., Motohashi, K. and Goto, A. (2010): Patent statistics as an innovation indicator, in: Hall, Bronwyn / Rosenberg, Nathan (eds.): *Handbook of the Economics of Innovation*, Volume 2, 1083-1127.

OECD (2009): OECD Patent Statistics Manual, Paris: OECD.

OECD (2013): OECD Science, Technology and Industry Scoreboard 2013, Paris: OECD, Available at: http://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2013/technological-advantage_sti_scoreboard-2013-55-en

Pakes, A. and Griliches, Z. (1984): Patents and R&D at the Firm Level: A First Look, in: Griliches, Zvi (ed.): *R&D, Patents, and Productivity*, Chicago: University of Chicago Press, 55-72.

Patel, P. and Pavitt, K. (1987): Is Western Europe losing the technological race? *Research Policy 16*(2), 59-85

Patel, P. and Vega, M. (1999): Patterns of internationalisation of corporate technology: Location vs. home country advantages. *Research Policy 28*(2), 145-155

Scherer, F. M. and Harhoff, D. (2000): Technology policy for a world of skew-distributed incomes, in: *Research Policy*, 29, 559-566.

Scherngell, T. (2006): *Interregionale Wissensspillovers in der europäischen High-Tech Industrie. Eine empirische Analyse.* Wiesbaden, DUV

Schmoch, U.(2008): Concept of a Technology Classification for Country Comparisons. Final Report to the World Intellectual Property Organisation, Geneva: WIPO, online at: http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf.

Soete, L. (1987): The impact of technological innovation on international trade patterns: The evidence reconsidered. *Research Policy 16*(2), 101-130

Ter Wal, A. L. and Boschma, R. A. (2009): Applying social network analysis in economic geography: Framing some key analytic issues. *The Annals of Regional Science 43*(3), 739-756

Wasserman, S. and Faust, K. (1994): *Social Network Analysis: Methods and Applications*. Cambridge, Cambridge University Press

Webster, E. and Jensen, P. H. (2011): Do Patents Matter for Commercialization?, in*: Journal of Law and Economics*, 54(2), 431-453.

Annex

Table 20: RTA indices for inventor per country and technology field, 2005-2014

Technology field	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Austria	1.20	0.65	0.48	0.45	0.68	0.60	0.52	0.98	0.32	0.86	1.27	1.19	0.95	0.48	1.18	0.97	0.97	0.45	0.47	1.46	0.92	0.67	0.85	0.89	1.57	1.77	1.14	1.52	1.25	1.18	1.14	0.88	2.12	1.15	2.26
Belgium	0.42	0.80	0.75	0.75	0.71	0.79	1.38	0.85	0.75	0.63	1.48	0.54	0.89	1.46	2.19	1.63	2.21	2.11	1.76	1.32	1.27	0.85	1.28	1.07	0.96	0.51	0.36	2.00	1.60	0.65	0.45	0.67	0.89	1.05	1.32
Bulgaria	0.84	0.37	0.98	0.30	0.49	1.81	3.52	0.29	0.24	0.74	0.04	2.14	0.64	0.32	0.30	0.79	0.24	0.89	0.80	0.98	0.83	3.32	1.42	1.78	2.20	1.16	1.77	0.93	1.79	1.25	0.25	0.69	1.18	2.35	3.11
Cyprus	0.43	0.37	0.68	1.05	-	0.79	2.00	0.07	0.26	0.41	-	4.30	1.55	0.19	1.67	3.89	0.18	1.25	0.30	0.15	0.53	-	0.87	1.74	1.12	-	1.59	0.77	1.04	0.61	0.81	0.55	2.42	0.19	4.08
Czech Republic	0.89	0.42	0.43	0.42	0.59	0.74	0.95	0.11	0.32	0.84	0.81	1.18	0.99	3.13	0.78	1.96	0.52	1.25	0.74	1.09	0.85	1.14	0.80	1.00	0.69	0.71	1.01	2.54	1.20	1.91	0.77	1.04	1.11	1.35	1.94
Germany	1.08	0.51	0.58	0.60	0.78	0.63	0.51	0.73	0.62	1.18	0.96	1.13	0.91	1.15	0.82	0.80	0.99	0.51	1.20	0.88	0.93	0.96	1.23	0.98	1.01	1.43	1.47	1.00	1.03	1.05	1.68	1.41	0.87	1.12	1.04
Denmark	0.58	0.94	0.83	0.78	0.69	0.60	0.64	0.17	0.35	0.79	1.53	0.72	1.88	0.81	3.25	2.19	0.19	3.07	0.70	0.48	0.41	0.73	1.30	1.10	1.12	0.54	1.78	0.58	1.23	1.59	0.78	0.35	1.19	0.64	1.97
Estonia	0.48	0.91	1.59	2.80	0.35	1.33	4.44	0.33	0.81	1.09	2.74	2.65	0.96	0.45	3.45	1.33	0.28	1.87	0.87	1.24	0.58	0.39	1.18	0.51	0.86	0.88	0.84	0.47	0.58	0.65	0.17	0.21	1.30	0.10	0.51
Spain	0.51	0.37	0.83	0.84	0.39	0.72	0.99	0.25	0.35	0.70	1.72	1.20	1.12	1.37	1.99	2.27	0.43	2.12	0.71	0.90	0.55	2.47	0.93	1.02	1.41	0.72	0.82	1.12	1.42	1.69	0.53	0.88	1.87	2.02	2.25
Finland	0.44	1.07	2.87	5.28	1.29	2.15	1.84	0.26	0.41	0.90	0.80	0.69	0.43	0.24	0.66	0.36	0.62	0.77	0.54	0.74	0.88	1.45	1.02	1.12	1.72	0.63	0.49	2.63	0.66	0.84	0.43	0.30	0.45	0.38	1.19
France	0.67	0.69	0.98	1.15	1.15	1.07	0.87	0.59	0.62	1.12	1.27	0.94	0.83	1.59	1.26	1.28	0.80	1.05	0.75	1.02	0.77	1.33	1.08	1.10	0.99	0.72	1.14	0.59	1.06	1.00	0.98	1.56	0.91	1.16	1.07
United Kingdom	0.58	0.67	1.11	1.31	0.89	1.25	1.83	0.41	0.59	1.20	1.85	1.18	1.45	1.33	1.37	1.59	0.40	0.99	1.25	0.50	0.58	0.70	1.08	0.88	1.05	0.58	0.85	0.71	0.81	0.65	0.73	0.63	1.73	1.45	1.84
Greece	0.43	0.35	1.00	1.07	0.81	0.63	2.18	0.33	0.14	0.56	1.53	1.40	1.18	1.10	0.90	2.67	0.41	2.13	0.98	0.49	0.52	0.35	1.01	1.15	0.85	2.38	1.64	0.62	1.36	1.40	0.52	0.82	1.99	0.93	2.06
Croatia	0.40	0.48	0.64	0.85	0.38	0.69	1.05	0.15	0.15	0.66	1.73	0.95	1.12	2.62	0.62	3.76	0.04	1.12	0.64	0.68	0.07	-	0.46	1.93	0.90	1.02	1.12	0.73	1.31	0.32	0.53	1.03	2.81	2.15	2.16
Hungary	0.86	0.47	0.64	3.65	0.18	0.68	1.42	0.06	0.51	0.62	1.25	1.07	0.87	2.53	1.17	2.62	0.21	1.42	0.63	0.62	0.26	1.32	0.90	0.87	0.81	0.78	0.71	0.27	0.88	1.21	0.57	0.80	1.41	0.79	1.17
Ireland	0.58	0.70	1.46	1.67	2.26	1.60	3.36	0.55	0.62	0.97	1.71	1.41	3.06	0.42	1.31	1.40	0.33	0.90	0.68	0.52	0.56	1.98	0.82	0.66	0.76	0.59	0.52	0.69	1.00	1.23	0.30	0.25	1.39	0.62	1.42
Italy	0.58	0.31	0.76	0.53	0.46	0.48	0.76	0.29	0.39	0.68	0.86	1.05	1.21	0.95	0.86	1.57	0.99	1.19	0.65	0.71	0.68	0.51	1.21	0.95	2.58	1.35	0.89	1.56	1.61	1.79	0.93	0.86	2.43	2.82	1.90
Japan	1.32	1.56	1.08	0.69	1.15	1.16	1.12	1.75	1.70	0.92	0.64	0.92	0.85	0.78	0.74	0.71	1.32	0.92	1.06	1.32	1.39	0.91	0.73	1.00	0.70	0.95	0.84	0.99	0.84	0.91	0.81	0.86	0.60	0.62	0.39
Lithuania	0.63	0.78	0.49	0.26	0.11	0.29	2.25	0.89	1.87	1.17	0.85	1.21	0.92	0.44	3.79	0.62	0.38	3.61	1.08	0.61	1.62	-	1.13	1.12	0.83	0.67	1.12	0.41	1.34	2.63	0.18	0.38	1.52	2.16	2.42
Luxembourg	0.65	0.37	0.56	0.58	1.58	0.59	1.58	0.48	0.29	1.00	0.50	0.69	0.90	0.24	0.53	0.83	0.48	0.39	0.51	4.35	1.55	-	0.74	0.67	0.95	0.82	1.23	0.21	2.04	5.77	1.52	1.43	0.37	0.74	1.63
Latvia	0.43	0.61	0.33	0.26	1.38	0.48	0.65	0.30	0.55	0.80	0.44	0.83	0.92	4.79	0.30	4.81	0.32	2.13	0.52	0.95	1.40	0.06	0.48	0.59	0.67	0.36	1.44	0.28	1.32	1.25	0.43	0.46	0.58	1.32	1.89
Malta	0.57	2.03	0.73	1.76	-	1.14	3.31	0.52	0.45	-	-	0.82	0.74	2.76	0.83	0.39	0.12	1.84	0.08	0.09	0.24	9.01	1.64	-	0.68	0.87	0.85	1.31	1.46	3.31	0.71	0.66	2.50	3.51	1.46
Netherlands	1.02	1.68	0.79	0.79	1.48	1.29	0.71	0.82	1.29	1.18	1.39	0.75	1.64	0.73	1.51	0.85	1.04	3.13	0.94	0.53	0.54	1.24	1.36	0.99	1.15	0.45	0.32	0.75	1.36	0.70	0.59	0.39	1.27	0.73	1.16
Poland	0.71	0.42	0.55	1.30	0.30	0.89	1.54	0.18	0.41	0.92	0.88	0.74	0.84	1.64	1.93	1.78	0.64	1.44	1.07	1.11	0.63	0.46	1.35	1.45	0.84	0.79	0.80	0.69	1.22	1.61	0.91	0.75	1.36	1.37	2.26
Portugal	0.31	0.42	1.06	1.20	0.44	0.61	1.79	0.30	0.32	0.85	1.85	1.52	1.09	1.36	2.22	2.38	0.51	1.61	1.00	0.79	0.84	1.19	1.43	1.23	0.88	0.56	0.88	0.80	1.13	1.61	0.53	0.70	2.36	1.55	1.77
Romania	0.58	0.87	1.43	1.32	1.42	3.79	1.51	0.08	0.33	1.22	0.18	1.01	0.98	0.15	0.44	0.66	0.18	0.43	0.72	0.68	0.50	0.36	0.81	1.46	0.29	0.45	1.80	0.06	0.57	1.34	1.12	1.26	0.86	1.06	2.37
Sweden	0.58	0.82	2.67	4.10	1.43	1.19	1.12	0.19	0.30	0.77	1.15	1.11	1.28	0.41	0.70	0.94	0.31	0.42	0.27	0.56	0.52	0.88	1.05	1.01	1.02	1.10	0.80	0.96	0.97	0.91	0.84	1.04	1.28	0.60	1.22
Slovenia	0.92	0.27	0.38	0.19	0.67	0.40	1.31	0.20	0.20	0.70	0.47	1.26	0.77	2.82	1.32	3.82	0.17	0.97	0.43	0.50	0.24	1.09	0.64	0.88	0.88	0.63	0.50	0.19	0.84	1.40	0.70	0.85	6.31	1.86	2.19
Slovakia	1.01	0.44	1.04	0.65	0.10	0.90	4.15	0.29	0.32	0.58	0.75	1.14	0.43	1.39	0.84	0.85	0.53	1.08	0.78	0.96	0.49	1.82	1.11	1.48	0.51	0.91	1.42	0.68	1.16	2.45	1.22	1.96	1.22	0.51	2.74

Technology field codes: 1. "Electrical machinery, apparatus, energy"; 2. "Audio-visual technology"; 3. "Telecommunications"; 4. "Digital communication"; 5. "Basic communication processes"; 6. "Computer technology"; 7. "IT methods for management"; 8. "Semiconductors"; 9. "Optics"; 10. "Measurement"; 11. "Analysis of biological materials"; 12. "Control"; 13. "Medical technology"; 14. "Organic fine chemistry"; 15. "Biotechnology"; 16. "Pharmaceuticals"; 17. "Macromolecular chemistry, polymers"; 18. "Food chemistry"; 19. "Basic materials chemistry "; 20. "Materials, metallurgy"; 21. "Surface technology, coating"; 22. "Micro-structural and nano-technology"; 23. "Chemical engineering"; 24. "Environmental technology"; 25. "Handling"; 26. "Machine tools"; 27. "Engines, pumps, turbines"; 28. "Textile and paper machines"; 29. "Other special machines"; 30. "Thermal processes and apparatus"; 31. "Mechanical elements"; 32. "Transport"; 33. "Furniture, games"; 34. "Other consumer goods"; 35. "Civil engineering"; Source EPO 2016

Table 21: RTA indices for applicants per country and technology field, 2005-2014

Technology field	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Austria	1.23	0.52	0.40	0.33	0.66	0.53	0.54	0.87	0.31	0.84	1.24	1.25	0.84	0.52	1.17	1.05	1.29	0.47	0.50	1.61	0.92	0.67	0.92	0.92	1.66	1.84	1.05	1.46	1.37	1.23	1.11	0.88	2.25	1.26	2.45
Belgium	0.43	0.61	0.50	0.44	0.59	0.68	1.06	0.72	0.70	0.65	1.71	0.51	0.90	1.66	2.45	1.98	2.03	2.14	1.62	1.48	1.31	0.88	1.31	1.09	0.98	0.56	0.36	2.14	1.60	0.87	0.43	0.63	1.12	1.72	1.31
Bulgaria	0.87	0.34	0.91	0.35	0.52	1.39	2.92	0.34	0.22	0.66	-	2.19	0.61	0.24	0.31	0.85	0.20	0.83	0.93	0.98	0.95	3.22	1.57	2.01	2.10	1.26	1.91	1.39	2.05	1.32	0.27	0.68	1.23	2.11	3.34
Cypress	0.41	0.48	1.38	0.52	0.04	0.91	2.00	0.29	0.37	0.41	0.67	2.41	1.09	0.31	1.39	3.24	0.29	1.05	0.72	0.75	1.44	0.88	1.17	1.50	1.31	0.19	1.60	1.21	1.11	0.37	0.61	0.75	1.76	2.97	2.69
Czech Republic	0.71	0.35	0.43	0.27	0.41	0.59	0.92	0.09	0.31	0.76	0.82	1.10	1.07	3.28	0.84	2.23	0.58	1.36	0.84	1.14	0.92	1.43	0.95	1.09	0.69	0.91	1.01	2.71	1.31	1.95	0.72	1.08	1.34	1.44	1.83
Germany	1.07	0.45	0.51	0.50	0.75	0.60	0.52	0.71	0.58	1.18	0.97	1.16	0.93	1.18	0.83	0.81	1.02	0.50	1.24	0.88	0.94	1.03	1.25	1.00	1.04	1.47	1.57	1.06	1.05	1.04	1.76	1.46	0.89	1.16	1.03
Denmark	0.55	0.82	0.64	0.47	0.55	0.54	0.65	0.16	0.32	0.79	1.67	0.72	1.92	0.88	3.53	2.26	0.22	3.42	0.75	0.52	0.42	0.63	1.41	1.10	1.20	0.54	1.89	0.57	1.36	1.55	0.79	0.36	1.23	0.66	2.05
Estonia	0.49	0.64	1.05	2.10	0.42	1.04	4.45	0.32	0.88	1.25	3.23	2.34	1.19	0.53	3.66	1.42	0.36	1.76	1.02	1.22	0.55	-	1.37	0.59	0.97	0.92	0.90	0.61	0.62	0.68	0.19	0.33	1.18	0.10	0.81
Spain	0.48	0.32	0.77	0.67	0.37	0.66	0.96	0.23	0.33	0.73	1.82	1.26	1.18	1.42	2.10	2.36	0.39	2.22	0.72	0.97	0.63	2.57	0.97	1.07	1.46	0.76	0.86	0.95	1.49	1.62	0.52	0.92	1.95	1.97	2.36
Finland	0.40	0.96	2.86	5.34	1.22	2.23	1.83	0.26	0.38	0.84	0.76	0.67	0.40	0.22	0.63	0.33	0.58	0.77	0.55	0.78	0.87	1.43	1.06	1.10	1.76	0.62	0.49	2.67	0.64	0.80	0.40	0.29	0.43	0.36	1.12
France	0.64	0.74	1.06	1.40	1.00	1.08	0.92	0.58	0.61	1.09	1.30	0.92	0.85	1.65	1.27	1.27	0.76	0.98	0.76	1.00	0.78	1.34	1.10	1.11	0.95	0.72	1.12	0.58	1.05	0.94	0.92	1.51	0.91	1.15	1.12
United Kingdom	0.57	0.60	0.99	1.05	0.83	1.26	1.87	0.40	0.59	1.18	1.97	1.23	1.41	1.35	1.47	1.73	0.38	1.05	1.22	0.53	0.59	0.75	1.16	0.97	1.10	0.57	0.81	0.73	0.86	0.66	0.75	0.67	1.89	1.54	1.96
Greece	0.42	0.32	0.79	0.52	0.60	0.51	2.11	0.29	0.12	0.57	1.64	1.56	1.18	1.13	0.92	2.69	0.40	2.28	1.00	0.53	0.56	0.37	1.01	1.31	0.96	2.73	1.84	0.62	1.58	1.51	0.58	0.89	2.03	0.98	2.20
Croatia	0.43	0.47	0.59	0.58	0.40	0.73	1.17	0.13	0.15	0.67	1.87	1.05	1.10	2.53	0.66	3.71	0.01	1.29	0.66	0.78	0.08	-	0.35	2.13	1.00	0.97	1.13	0.63	1.44	0.25	0.58	1.12	3.01	2.25	2.27
Hungary	0.69	0.46	0.53	2.40	0.19	0.67	1.65	0.05	0.57	0.68	1.47	1.24	1.03	2.71	1.33	2.96	0.23	1.71	0.72	0.74	0.29	1.60	1.00	0.97	0.97	0.72	0.80	0.36	1.00	1.43	0.53	0.64	1.64	0.94	1.32
Ireland	0.52	0.62	1.24	1.26	1.46	1.41	3.14	0.38	0.58	0.91	1.87	1.50	2.92	0.78	1.44	2.25	0.34	1.02	0.63	0.60	0.56	1.79	0.86	0.70	0.75	0.62	0.53	0.65	1.06	1.18	0.30	0.29	1.64	0.64	1.59
Italy	0.55	0.29	0.61	0.42	0.36	0.43	0.77	0.28	0.38	0.70	0.90	1.09	1.26	0.97	0.89	1.59	1.03	1.27	0.64	0.72	0.72	0.54	1.29	1.02	2.78	1.44	0.88	1.68	1.73	1.77	0.98	0.90	2.52	2.52	2.02
Japan	1.34	1.59	1.11	0.74	1.20	1.17	1.10	1.71	1.68	0.92	0.63	0.91	0.84	0.74	0.73	0.69	1.29	0.90	1.02	1.28	1.36	0.91	0.72	0.98	0.70	0.94	0.82	0.98	0.83	0.96	0.79	0.85	0.60	0.64	0.37
Lithuania	0.61	0.63	0.48	0.19	0.11	0.23	2.37	0.75	1.73	1.16	0.66	1.14	1.17	0.52	4.28	0.76	0.48	4.08	1.07	0.73	0.88	-	1.06	1.12	0.68	0.65	1.17	0.40	1.57	2.65	0.19	0.40	1.56	1.80	2.52
Luxembourg	0.83	0.37	0.66	0.37	1.02	0.71	1.44	1.08	1.24	0.68	0.45	0.64	1.86	0.60	0.69	1.14	0.34	0.64	0.41	3.10	1.08	0.40	0.66	0.73	0.72	0.71	1.90	0.34	0.79	2.35	1.20	1.08	0.68	1.46	2.17
Latvia	0.41	0.56	0.24	0.24	1.29	0.54	0.64	0.24	0.53	0.79	0.47	0.85	1.01	4.65	0.31	4.76	0.34	2.29	0.55	0.92	1.60	0.05	0.51	0.43	0.66	0.72	1.40	0.39	1.32	1.26	0.45	0.49	0.61	1.42	1.97
Malta	0.26	0.64	0.14	0.69	-	0.62	0.81	0.09	0.24	1.47	0.16	5.74	4.51	1.00	0.76	2.24	0.54	0.51	0.49	0.08	0.74	2.27	1.36	0.44	1.50	0.82	0.42	0.53	0.73	0.58	0.34	0.37	1.95	1.32	1.67
Netherlands	0.95	1.52	0.78	0.74	1.57	1.39	0.71	0.85	1.20	1.28	1.34	0.75	1.66	0.92	1.45	0.86	1.16	3.06	1.23	0.49	0.50	1.15	1.30	0.95	1.11	0.40	0.30	0.78	1.28	0.62	0.48	0.36	1.23	0.74	1.35
Poland	0.61	0.33	0.46	0.81	0.23	0.71	1.52	0.15	0.37	0.89	0.99	0.72	1.01	1.77	2.18	1.98	0.67	1.65	1.17	1.11	0.65	0.51	1.46	1.55	0.86	0.85	0.85	0.74	1.27	1.69	0.96	0.72	1.51	1.57	2.47
Portugal	0.30	0.42	1.01	1.04	0.33	0.49	1.85	0.30	0.33	0.89	1.91	1.53	1.13	1.33	2.35	2.47	0.50	1.80	1.11	0.80	0.84	1.29	1.40	1.32	0.97	0.63	0.89	0.85	1.23	1.37	0.44	0.69	2.62	1.49	1.93
Romania	0.54	0.80	1.05	0.90	1.15	3.42	1.92	0.08	0.35	1.27	0.21	1.16	1.35	0.17	0.53	0.74	0.27	0.45	0.87	0.89	0.60	0.41	0.89	1.86	0.42	0.53	2.09	0.07	0.60	1.11	0.79	0.88	1.17	1.39	2.60
Sweden	0.44	0.70	2.91	4.67	1.52	1.09	1.15	0.16	0.28	0.79	1.08	0.99	1.19	0.43	0.63	0.93	0.22	0.37	0.24	0.51	0.45	0.83	0.98	0.93	0.88	1.08	0.74	0.78	0.95	0.85	1.01	1.13	1.19	0.71	1.24
Slovenia	0.93	0.23	0.35	0.12	0.70	0.34	1.39	0.20	0.17	0.73	0.52	1.09	0.83	3.19	1.39	4.14	0.17	1.10	0.48	0.55	0.25	1.29	0.67	0.79	0.94	0.67	0.55	0.23	0.88	1.47	0.68	0.89	5.00	1.84	2.30
Slovakia	0.90	0.38	0.92	0.45	0.10	0.87	4.64	0.29	0.28	0.69	0.87	1.24	0.50	1.09	0.77	0.83	0.49	1.21	0.99	1.00	0.43	1.89	1.16	1.67	0.98	1.30	1.48	0.63	1.21	2.51	1.23	1.69	0.92	0.65	3.13

Technology field codes: 1. "Electrical machinery, apparatus, energy"; 2. "Audio-visual technology"; 3. "Telecommunications"; 4. "Digital communication"; 5. "Basic communication processes"; 6. "Computer technology"; 7. "IT methods for management"; 8. "Semiconductors"; 9. "Optics"; 10. "Measurement"; 11. "Analysis of biological materials"; 12. "Control"; 13. "Medical technology"; 14. "Organic fine chemistry"; 15. "Biotechnology"; 16. "Pharmaceuticals"; 17. "Macromolecular chemistry, polymers"; 18. "Food chemistry"; 19. "Basic materials chemistry "; 20. "Materials, metallurgy"; 21. "Surface technology, coating"; 22. "Micro-structural and nano-technology"; 23. "Chemical engineering"; 24. "Environmental technology"; 25. "Handling"; 26. "Machine tools"; 27. "Engines, pumps, turbines"; 28. "Textile and paper machines"; 29. "Other special machines"; 30. "Thermal processes and apparatus"; 31. "Mechanical elements"; 32. "Transport"; 33. "Furniture, games"; 34. "Other consumer goods"; 35. "Civil engineering"; Source EPO 2016