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Transnational Patents – Structures, Trends and Recent Developments

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1. Introduction

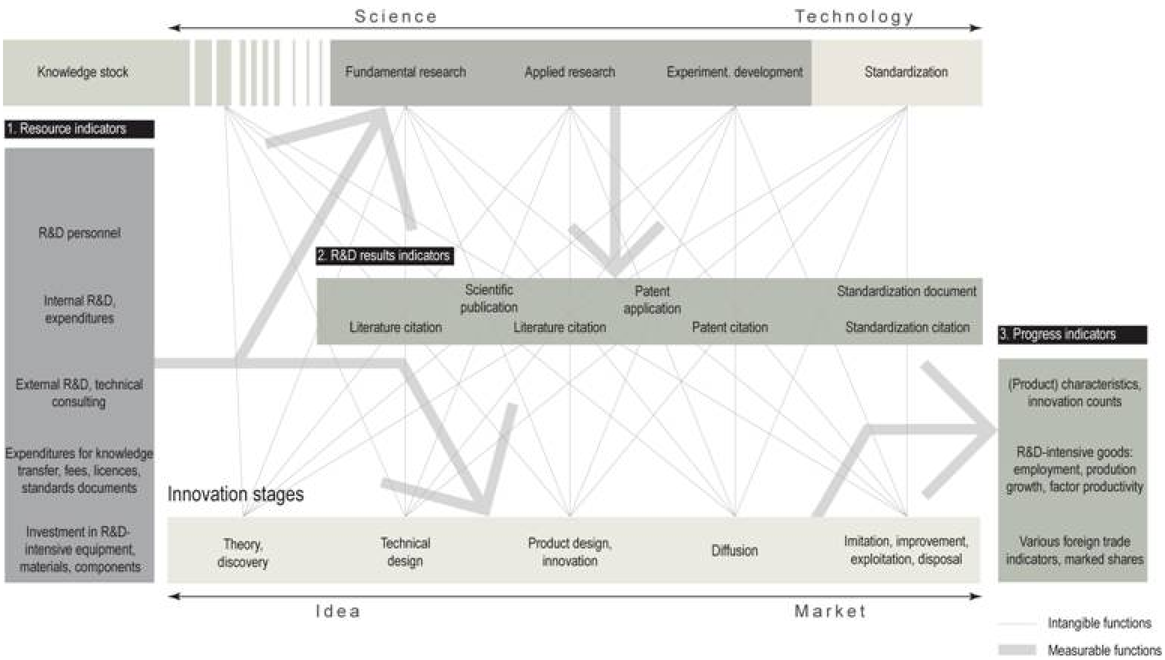
Many kinds of intellectual property rights exist like copyrights, trademarks, design or utility patents, which can be labelled as formal rights. The use of these formal rights often goes hand in hand with each other, but also with informal rights, among them are secrecy, head start into the market, complex design, or complex technical specifications. However, not all formal and informal rights perfectly fit and some even exclude each other – like patenting and secrecy. Beneath the mechanisms of protection, patents for technical innovations play a special and crucial role, as the formal requirements for patent applications are the strictest ones, and the assertion of patents is backed by a strong legal framework. Any patent has to pass an extensive examination procedure in the patent office(s), done by examiners skilled and trained in the field.

A patent application has to satisfy at least three criteria: novelty, inventive step and industrial applicability. The criterion of novelty implies world-wide novelty, meaning that any patent filing, any application or use, and even any publication of the technology – at least in almost all countries – will prevent a grant of this patent, as this is considered prior art and inhibits patent protection. The second criterion – the inventive step – means that an inventive act had to take place, which is defined by the fact that the new idea is not obvious to a person skilled in the art and also has to go beyond triviality. The third requirement of industrial applicability demands that an economic use is possible in principle, but it does not mean that the applicant has to have the technology ready to be sold at the day of applications. This criterion is almost generally fulfilled because of the considerable costs of patent applications that the huge majority of patents require and which are only spent with a realistic market perspective.

Used as an innovation indicator, patents form an important output indicator for innovation systems analyses and the assessment of the technological competitiveness of nations. Especially international patent filings are meaningful for comparisons, as these reflect activities on international markets where national and multinational companies meet with their competitors directly and on neutral grounds. The data applied here is a concept recently suggested by Frietsch and Schmoch (forthcoming) and already used in earlier analyses of this kind (Frietsch et al. 2008), which is able to overcome the home advantage of domestic applicants so that a comparison of technological strengths and weaknesses becomes possible – beyond home advantages and unequal market orientations. In detail all PCT applications are counted whether transferred to the EPO or not and all direct EPO applications without precursor PCT application. Double counting of transferred Euro-PCT applications is excluded. More simply speaking: all patent families with at least a PCT application or an EPO application are taken into account.

Starting from a simple legal perspective, patents give an exclusive right of usage to the applicant for a limited period. In addition, patents can be interpreted as an indicator of the codified knowledge of enterprises, and, in a wider perspective, of countries. As an innovation indicator, patents fit into a system of further indicators to describe scientific and technological competitiveness and to analyse innovation systems. The role of patents is here to be seen as an intermediate measure. Intermediate in so far as it covers the output of R&D systems to which expenditures or human capital are input to. At the same time patents form the input to the market activities, which are reflected for example by foreign trade, turnover or qualified labour. Patents are especially dedicated to measure the output of industrial R&D activities, whereas scientific publications are still the most important output for the public research system, though this latter group of institutions also contributes to the patent production. However, recent examinations have found shares of public research in total patenting of 3-5% (Lissoni et al. 2008; Schleinkofer 2008). A representation of innovation indicators and their relation are depicted in Figure 1.

Figure 1: Indicator System to Analyse Innovation Systems Performance



Source: Grupp 1997; further developed and designed by Fraunhofer ISI.

This report intends to give a brief overview over the developments in Transnational Patent applications since the early 1990s with a special focus on the recent trends and structures. Chapter 2 presents total trends, growth rates, intensities (patents per 1 Mio. workforce) and specialisation[1] indices, which are designed to reflect patent structures beyond size effects of countries and technology fields. Chapter 3 will discuss patent applications from small and medium-sized enterprises (SMEs) in relation to filings from large companies and public research institutions. The fourth chapter analyses international co-patenting structures especially of German inventors. However, it also applies an internationally comparative approach.

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1 The specialization index RPA (Revealed Patent Advantage) is defined as:

$$RPA_{kj} = 100 * \tanh \ln [(P_{kj}/\Sigma_j P_{kj})/(\Sigma_k P_{kj}/\Sigma_{kj} P_{kj})] . \qquad (1)$$

with P_{kj} indicating the number of patent applications of country k in the technology field j. Positive values point to the fact that the technology has a higher weight in the portfolio of the country than its weight in the world (all applications from all countries at EPO). Negative values indicate specializations below the average, respectively.

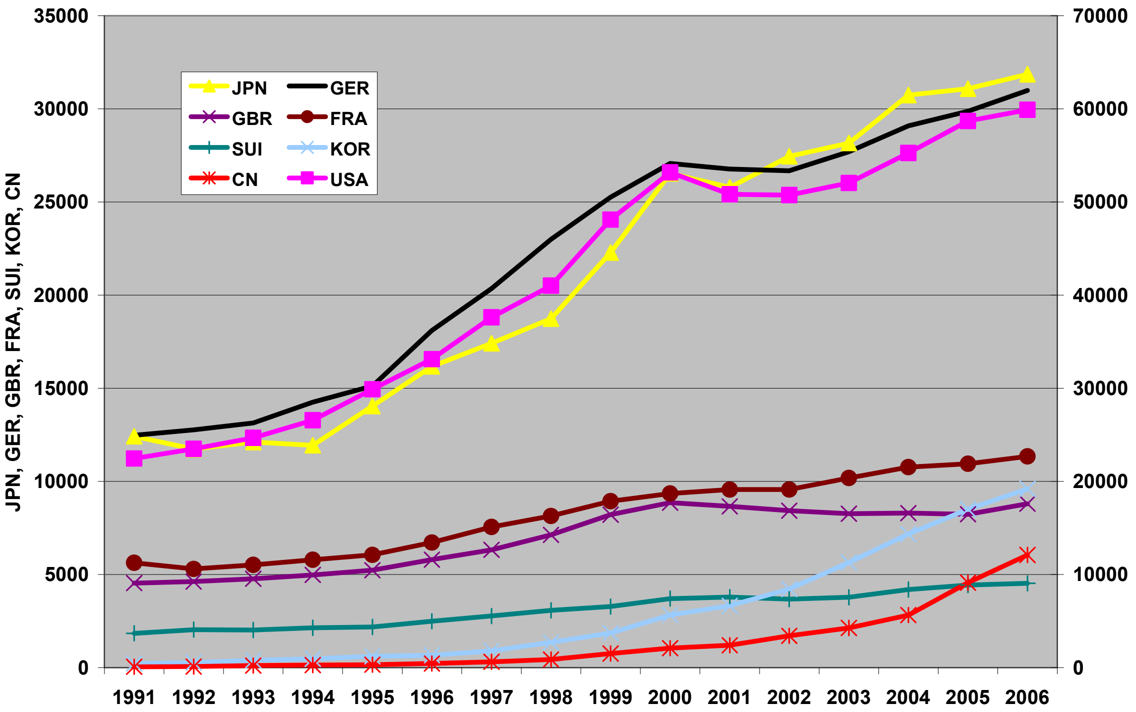
2. Trends in International Patent Applications

The number of patent applications on the international level has been growing very fast in the second half of the 1990s, due to several reasons (Janz et al. 2001; Kortum/Lerner 1999). First of all, there was an increase in R&D expenditure and a growing importance of technological capabilities. Emergence and growing importance of technology-intensive sectors such as Biotechnology or Nanotechnology have contributed to this development (van Zeebroeck et al. 2007). Also, part of growth can be explained by an increased efficiency in research and development and productivity growth of researchers. However, these facts alone are not able to explain the entire growth of transnational patent filings. Further explanations include a growing tendency of international filings instead of pure national filings. So what has been applied for only at the national level before is now more and more also applied for on an international level. This tendency is partly driven by more globalized business environment and partly by diffusion of harmonized patenting procedure such as PCT route (van Zeebroeck et al. 2007). Finally, an increasing propensity to patent (Hall/Ziedonis 2001; Kortum/Lerner 1999), particularly driven by strategic patenting, should account for part of growth in combination with other explanations. This means that contemporary firms more and more used patents as a mean for their strategic technology development (Arundel/Patel 2003; Lang 2001; Macdonald 2003), to get access to financial sources – e.g. via banks or venture capital funds, which prefer to have a codified idea in hand than only in the minds of the entrepreneurs –, as an instrument of active blocking of competitors or just as another mean of gratification of their employees (Blind et al. 2006).

After 1994 in almost all countries displayed in Figure 2 an extreme upsurge of patent filings is visible. After the year 2000 this development was discontinued caused by the economic downswing of this period, which especially affected the leading-edge[2] technologies like Information and Communication Technologies (ICT), Pharmaceuticals and Biotechnology. Countries that are considerably active in these fields suffered more than others. The fact that Germany has a strong focus on high-level technologies prevented it from a drastic downturn. The impact of this economic crisis on the fast growing and emerging countries like Korea and China was much smaller. At least the positive trend of patent applications has been going on, though with a slower slope as these countries highly rely on ICT, too. The case of UK – a country that traditionally has a strong orientation towards the US market and is therefore slightly underrepresented in by this transnational perspective – did not suffer as much as the ICT-oriented countries, but it took them also longer to recover from this shock.

2 High-Tech sectors and technologies are defined by their R&D-intensity. For a more detailed and differentiated analysis High-Tech is split in the two areas of high-level technologies, which (usually) demand an R&D-intensity of 2.5-7% and leading-edge technologies usually require investments that are even beyond 7% (Legler/Fritsch 2007).

Figure 2: Absolute number of Transnational Patent Applications, 1991-2006



Source: Questel (EPPATENT, WOPATENT); Fraunhofer ISI calculations, update September 2008.

It can be seen in Figure 2 that the USA file twice as much patents on the international level than Japan and Germany and about three times more than France, Korea and the United Kingdom. The latter has even been surpassed by the Koreans in absolute terms since 2005 and now only ranks 6 on the transnational level. And they might fall even behind the Chinese in the next years to come. In terms of High-Tech patents (see Table 1) – these are technologies with at least an R&D investment of 2.5% – China is still more behind and only ranks 7 in the world, but Table 1 also shows the strong trend in China, which was able to file 20 times more High-Tech patents in 2006 than in 1997. Korean inventors have increased their activities almost 10 times in this period, whereas the average total growth was about 1.8. However, in terms of intensities – these are the numbers of patents in relation to the number of workforce – China is still lagging far behind. On the other hand one could also say that, based on the size of the country in terms of population or employment, a further growth can be expected. Most of the other nations between 100 and almost 600 High-Tech patents per 1 million employment with Italy ranging at the bottom among the countries under consideration here and the two Scandinavian countries Sweden and Finland and first of all Switzerland at the top of this list. However, smaller countries have a relative advantage when this indicator is used. Among the large innovation oriented countries it is Germany that prevails, but especially the Japanese haven been able to shorten the gap in the recent years.

Table 1: Core Indicators for High-Tech Patents, 2006

	High-Tech			Total
	absolute	Growth (1997=100)	Intensities (employment)	Growth (1997=100)
Total	120742	178	---	181
EU-27	42340	157	192	155
USA	38327	150	261	159
JPN	20034	171	312	183
GER	17516	155	448	152
FRA	6687	158	265	150
KOR	6277	975	271	1054
GBR	5442	140	173	139
CN	4377	2021	6	1914
ITA	2973	167	119	177
CAN	2847	203	170	208
NED	2618	155	312	171
SUI	2472	174	576	163
SWE	2408	139	544	131
FIN	1367	146	560	152

Source: Questel (EPPATENT, WOPATENT); Fraunhofer ISI calculations, update September 2008.

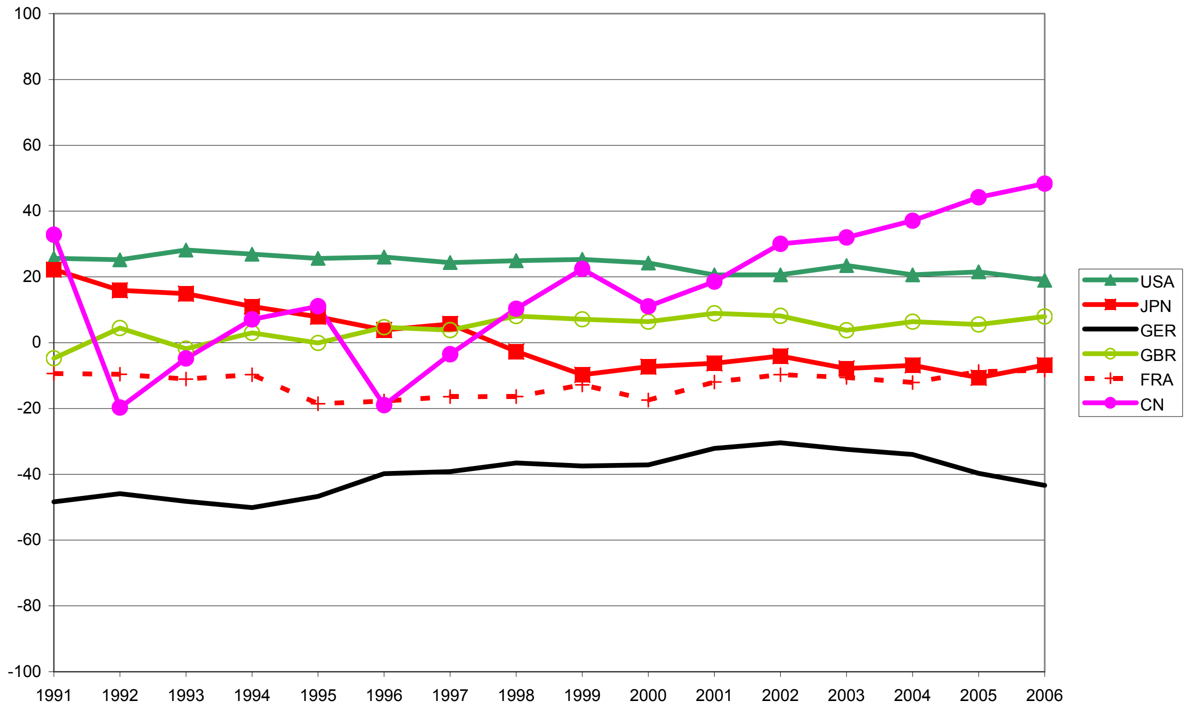
As already mentioned, leading-edge technologies as a sub-group of High-Tech, defined by the investment in R&D that this technology (or sector) usually demands – at least in Germany and the other OECD countries. Leading-edge technologies are defined as any technology where 7% or more of the turnover is re-invested in research and development (Legler/Fritsch 2007). However, some doubts and concerns were raised if this definition also holds for the Chinese technologies especially emerging out of the ICT sector (Frietsch/Wang 2007; Krawczyk et al. 2007; Legler/Krawczyk 2006). The impressive increase of the Chinese specialisation index[3] in leading-edge technologies – as depicted in Figure 3 – is mainly driven by Information and Communication Technology patents as well as a considerable number of filings in the Biotech/Pharmaceutical technologies.

As can be seen from Figure 3, Germany's relative position in leading-edge technologies has improved earlier in this decade, but nowadays takes a downward trend. The reasons for the relative improvement was argued to be a direct implication of the economic downswing after 2001 that especially affected the leading-edge sectors and technologies like Biotech/Pharmaceuticals and ICT (Frietsch et al. 2008; Frietsch/Schmoch 2006). The recovery and upturn of these industries in the recent years has made the German position go down, as Germany is strong in high-level technologies and associated leading-edge technologies, e.g. in the automobile and machinery sectors, where ICT plays an important role as a supplementary or even enabling input. However, the ICT sector in Germany is not as broad and focused on general technologies of this field as to sustain the massive increase in filings in this area – please keep in mind that ICT and Electronics alone accounts for 15% of total Transnational Patent applications and for about 25% of all High-Tech patents. With respect to leading-edge tech-

3 For a definition of the specialisation index please refer to footnote 1.

nologies, Germany is now back at the same relative international level like it was in the early 1990s. So the enormous rise of applications from China – 44% of China's Transnational Patents were filed in ICT or Electronics in 2006 – and also the focus of the Korean industry in this field – Koreans have been able to almost quadruple their international ICT and Electronics filings since 2001 – makes the German position hard to keep. Furthermore, smaller countries like Finland, Sweden and recently also Canada have been able to push their relative position in this respect. In addition, also Biotech/Pharma has recovered as more venture capital and also more other sources of funds for R&D investment are available again. As a direct consequence also here the patents are on a rising path. This fact is especially visible in the development of UK, where these kinds of technologies form a core part of the economic and technological strength – thus even almost the only one together with other chemistry-related areas, as can be seen from the rather low patent intensity displayed in Table 1.

Figure 3: Specialisation of selected countries in leading-edge technologies, 1991-2006



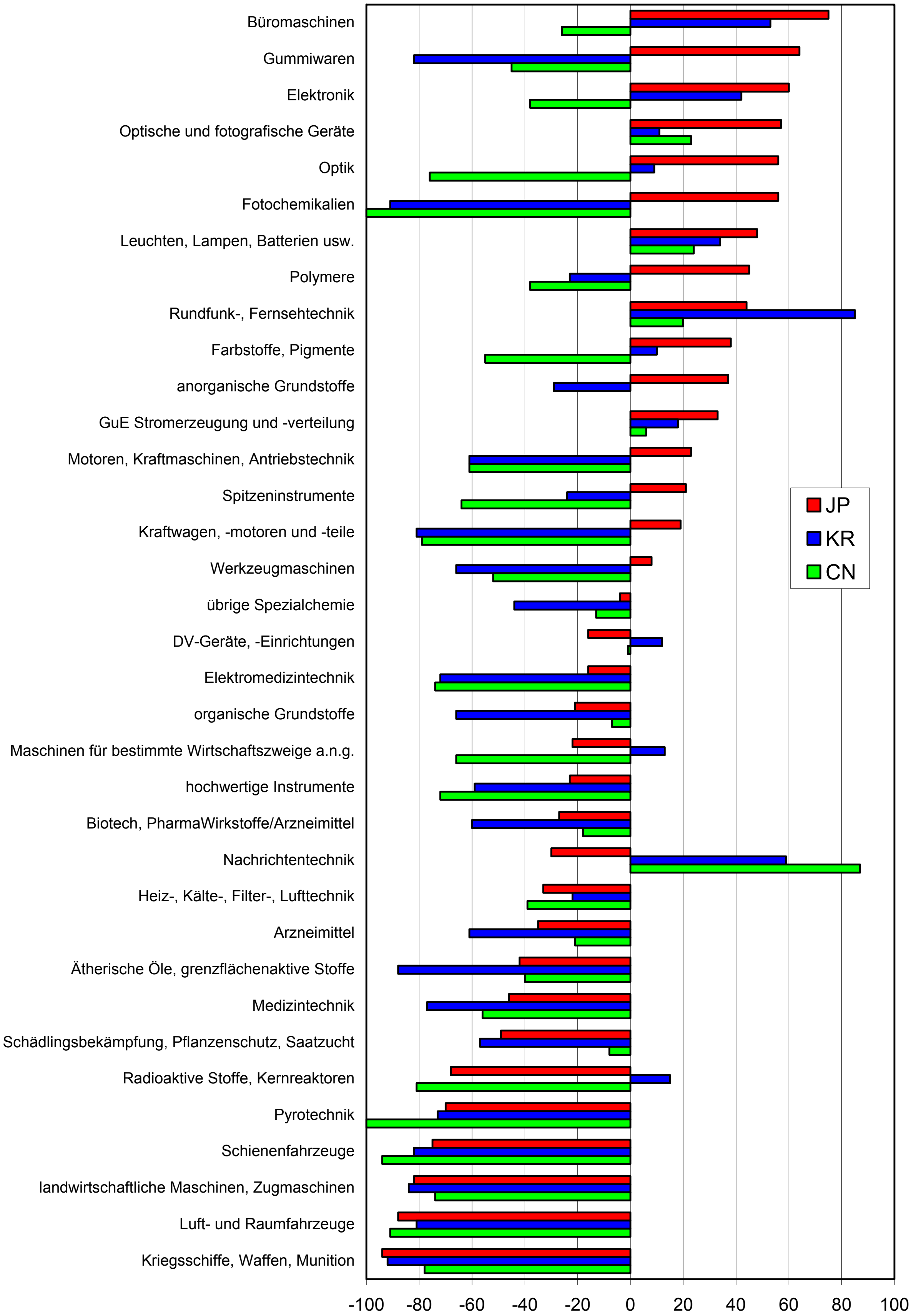
Source: Questel (EPPATENT, WOPATENT); Fraunhofer ISI calculations, update September 2008.

However, it was and is especially Japan that gets under pressure by the new and further emerging countries like Korea and China. Their specialisation profile is pretty similar in some core technologies to the Japanese activities. Figure 4 compares the profiles of Japan, China and Korea for the period 2004-2006. Japan still has some traditional strength for example in Office Machinery, Electronics and also Optical and Photo Apparatus. Conversely, the most prominent area where they have lost ground is that of television and broadcasting technologies. Some of their relatively advantageous positions in ICT vanished, though not with the same pace as the others have been growing, which means that they also have been able to increase their technology output in these fields. By the end of the last century Japan has been able to recover from the Asian crisis that stroke them almost over the whole period of the

1990s. Japan was therefore ready to get on an upward technology track – driven by increasing R&D investment – when the worldwide recession started its effects in the early 2000s. This again first of all holds for ICT and Electronics, where similarities and competition with the other Asian countries are visible. At the same time Japan has also been able to maintain its position in other traditional areas of their strengths, namely the Automotive and some parts of the Chemistry technologies. On the other hand, these are the areas where they have also considerable overlap and are therefore in a competition with the western countries, say USA and Germany among others. Figure 5 compares the German, US-American and Japanese technology profiles in High-Tech areas. Germany's competitive advantages are in the automotive sectors and the related technologies and here competition with the Japanese exists, while the US-Americans are hardly prevailing in these fields. Next to colours and pigments, electrical energy, as well as Polymers there are hardly any overlaps of the German profile with that of the two other countries under examination here. So the German profile is rather unique and clearly structured – though with a focus on moderately R&D-intensive technologies (or high-level technologies according to our terminology). The competition between the USA and Japan, on the other hand, cannot be neglected, but restrict themselves to some areas like Electronics, Optics and selected Instruments.

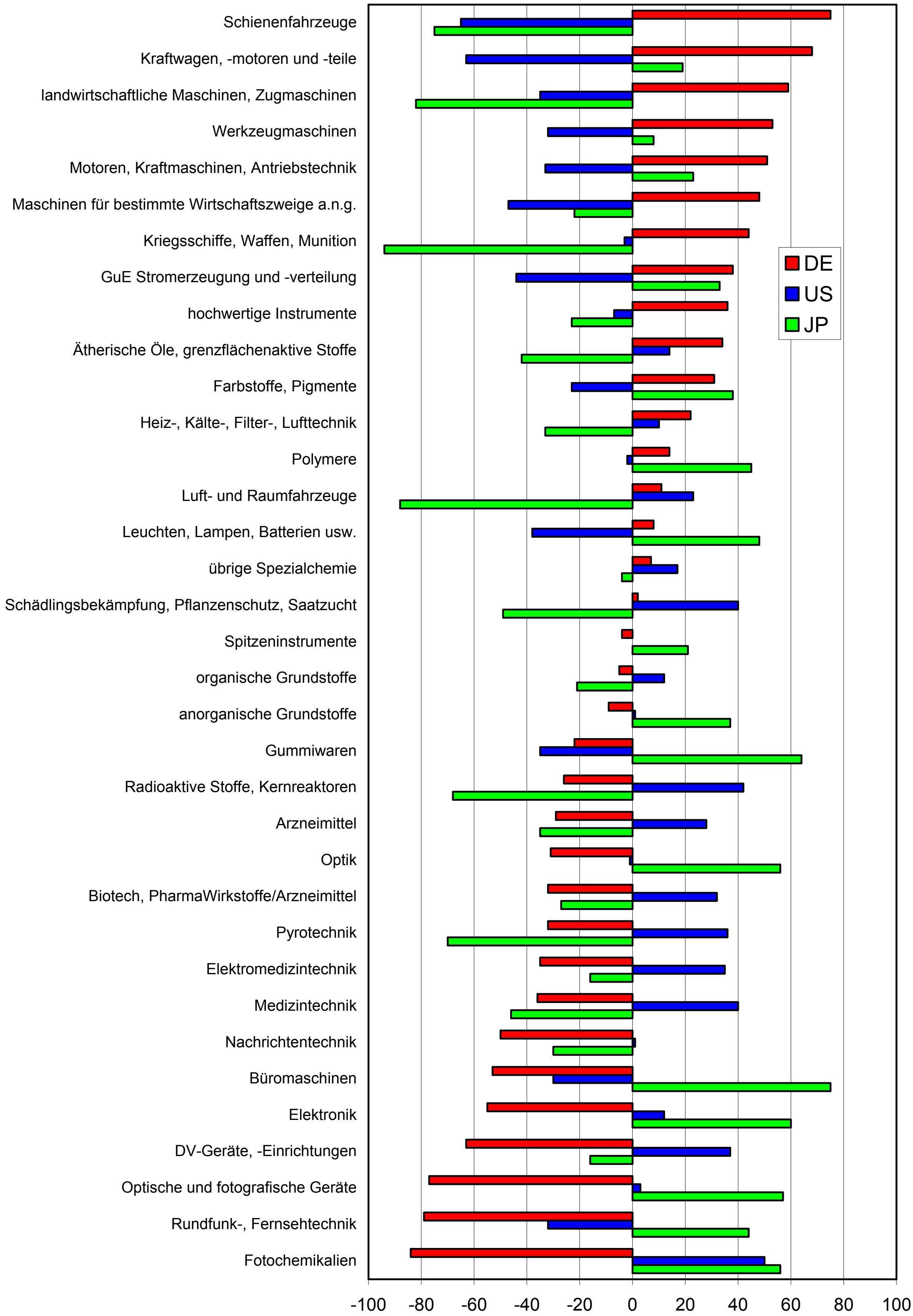
It will be interesting to see how the Japanese cope with the competition and pressure that they face from different continents. At least for the moment it seems that they are well prepared and they will be able to further sharpen their international technology profile, given the technology trends presented above. Taking the recent innovation policy measures into account it also seems that they are able to keep a sustainable path (Fraunhofer-ISI et al. 2008). However, they are still doing much of their R&D activities at home and they are hardly linked-up with international research (see also the report on Bibliometrics by Schmoch and Qu; see also chapter 4 on co-patenting). It has to be proved that this still is an adequate and up-to-date strategy of technology production. At least Germany has taken an alternative approach and has also taken an alternative innovation policy approach. Based on the so called "Hightech Strategy" coordination between different policy actors in Germany and a core focus on the optimisation of exchange processes between public and private research as well as national and international collaborations, Germany aims at keeping a leading position in international technology production. Freedom of research and support for small and medium sized enterprises (SMEs; see the following chapter) further characterise the recent philosophy of German innovation policy. Future comparisons with Japan will allow interesting deductions also on the quality, efficiency and effectiveness of innovation policy approaches and policy strategies, as the Japanese still follow a more top-down philosophy with alternative means for the conversion of policies into action (e.g. by "White Books"). The overlap of the profiles and the extraordinary orientation towards international markets makes them sufficiently similar, but the innovation policy seems to be almost completely different.

Figure 4: Patent Specialisation of Asian Countries, 2004-2006



Source: Questel (EPPATENT, WOPATENT); Fraunhofer ISI calculations, update September 2008.

Figure 5: Patent Specialisation of the Three Largest Patenting Countries, 2004-2006



Source: Questel (EPPATENT, WOPATENT); Fraunhofer ISI calculations.

3. Patent Applications by Small and Medium-sized Enterprises (SMEs)

In terms of R&D activities, the orientation towards international markets and also concerning the sectoral orientation, small and medium-sized enterprises (SMEs) are different from their larger counterparts. SMEs are usually defined by the number of employees and/or by their annual turnover. In the European context, the number of employees is usually below 250. However, in Germany it is rather common to define all companies as small or medium-sized, which have less than 500 employees. This latter definition is also applied here.

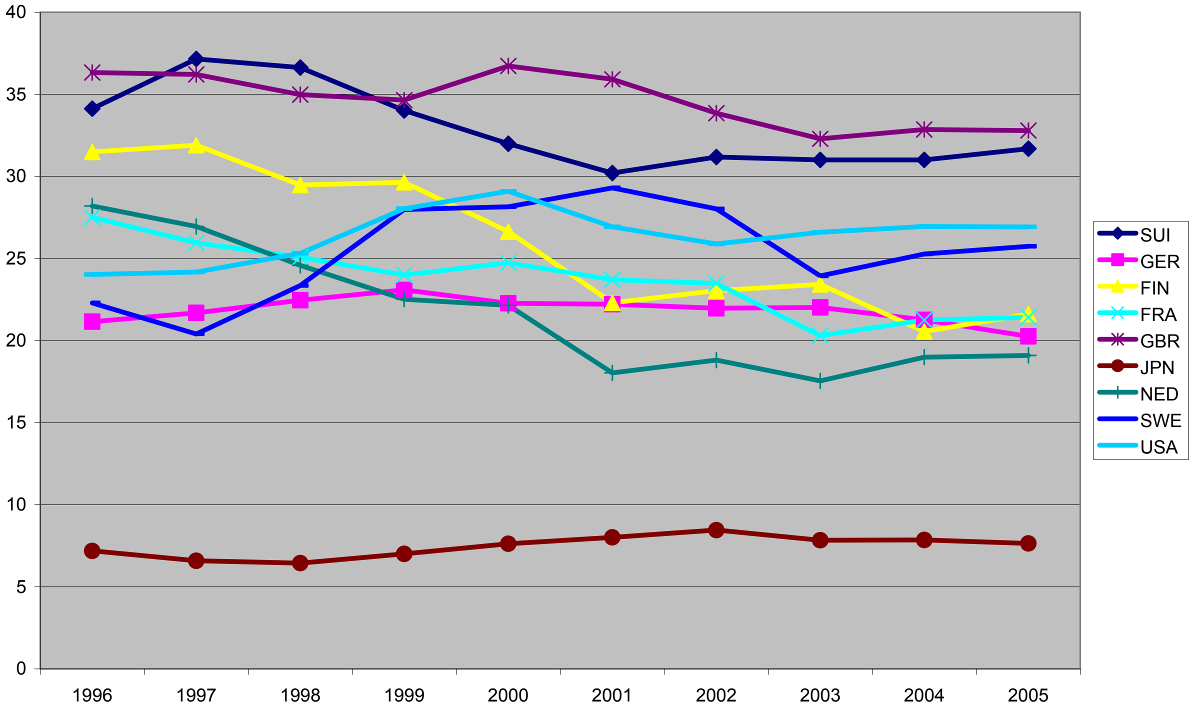
It has to be stressed that additional company information like sales volume, number of employees or R&D expenditure are not available in regular patent databases. Patent databases are just containing information on applicants and inventors that are relevant to the application process as such. To be able to analyse the size dimension of patent applicants, it was necessary to match the patent database – in our case PATSTAT – with external data sources containing company information. For the European countries we have used the database called AMADEUS and for the USA and Japan the data was extracted from Dun & Bradstreet company database. Both data sources have been supplemented by Internet searches for those applicants, which could not be retrieved in these databases. As the number of distinct applicant names is considerably high, especially when the large countries USA, Japan, Germany, France, and the United Kingdom are taken into account, a feasible approach had to be used. After the consolidation of the applicant names – all free inventors where the applicant and the inventor names are identical have been excluded –, all applicants filing less than three patents a three years period were classified as small companies by definition. Universities and research institutes where classified separately. All the remaining applicant names were locked up in the patent databases or in the Internet and were classified according to the number of employees in the most recent available year. The rule of three patents in three years has proved to be fruitful and reliable approach to reduce the number of names to be classified also in earlier studies (Kinkel et al. 2008). And even if a few of these applicant names are misclassified as being small or medium-sized, the impact on the overall outcome is restricted as the total number of patent applications – and this is the level of our analysis –is mainly driven by the large applicants.

Figure 6 displays the shares of patents by small and medium-sized enterprises in nine countries between 1996 and 2005. In most of the countries the shares are decreasing within the observation period, suggesting that other applicant types have been able to increase their shares. Figure 7 shows the shares for large companies in our database, which are rather stable or also shrinking for most of the country. In consequence, it is especially universities and research institutes, but also some independent inventors, which have been able to increase the numbers and shares of patent applications. The data depicts transnational patent applications, identical to the approach applied in the previous section.

Different levels of SME engagement can be derived from these two graphs. While the shares of small and medium-sized enterprises in Japan are below 10%, ranging at the lower end of the scale of the nine countries under examination here, the shares are well above 30% for

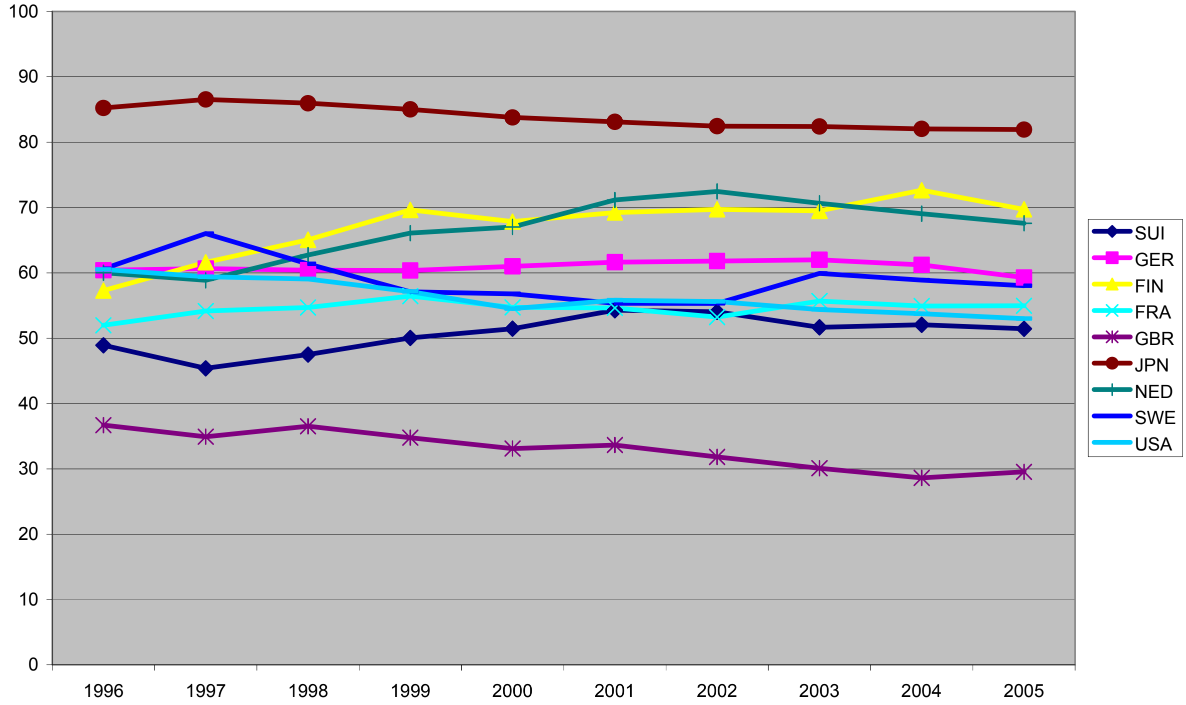
Switzerland and the United Kingdom. In consequence, large enterprises account for more than 80% of the patent applications at the transnational level in Japan and for less than 30% in the case of the United Kingdom. This leaves a large share for universities and research institutes, but especially free and independent inventors in the UK. The engagement of SMEs seems not to be dependent on the size of the country.

Figure 6: Shares of SME's Transnational Patent applications, 1996-2005



Source: EPO worldwide patent database (PATSTAT); Fraunhofer ISI calculations, update September 2008.

Figure 7: Shares of large enterprises' Transnational Patent applications, 1996-2005



Source: EPO worldwide patent database (PATSTAT); Fraunhofer ISI calculations, update September 2008.

Table 2: Absolute number of Transnational Patent applications by SMEs, 2003-2005

	SUI	GER	FIN	FRA	GBR	JPN	NED	SWE	USA
Audio-visual electronics	90	202	35	192	223	187	59	61	1178
Basic chemicals, petroleum prod.	361	1083	80	516	688	840	270	148	3289
Computers, office machinery	331	825	133	502	972	873	227	292	6524
Electrical machinery, energy	203	887	59	371	383	558	102	119	2181
Electronic components	152	683	58	157	229	602	127	77	1844
Energy machinery	193	1034	33	240	360	400	77	138	1575
General machinery	324	1264	189	444	452	320	321	181	1659
Machine-tools	245	1039	46	217	147	326	74	97	823
Measurement, control	705	1640	135	534	856	809	242	318	3996
Medical equipment	732	1390	123	720	983	703	319	386	6846
Metal products	266	1269	46	413	386	203	178	154	997
Non-polymer materials	394	1596	128	479	407	796	219	161	2517
Optics	96	374	49	180	236	366	138	62	1193
Pharmaceuticals	693	1391	158	909	1661	1187	418	426	7529
Polymers, rubber, man-made fibres	528	1567	82	774	806	819	508	206	2867
Special machinery	548	1921	176	677	766	682	476	256	2785
Telecommunications	267	762	225	395	771	541	163	293	4440
Textiles, domestic appliances, food	653	1456	151	817	842	801	492	261	3691
Transport	265	1533	61	602	563	482	234	225	2011
Total	7046	21916	1967	9139	11731	11495	4644	3861	57945

Source: EPO worldwide patent database (PATSTAT); Fraunhofer ISI calculations, update September 2008.

Table 3: Shares of Transnational Patent applications by SMEs, 2003-2005

	SUI	GER	FIN	FRA	GBR	JPN	NED	SWE	USA
Audio-visual electronics	29,8	15,6	9,5	13,2	34,9	2,8	5,0	23,5	23,2
Basic chemicals, petroleum prod.	22,7	14,8	33,1	20,1	23,5	9,2	15,0	30,8	22,5
Computers, office machinery	33,7	14,1	13,3	14,9	31,9	4,4	5,7	32,6	25,8
Electrical machinery, energy	26,6	16,8	26,2	19,3	45,4	7,2	14,4	34,7	29,4
Electronic components	35,5	19,2	41,4	12,7	28,3	5,2	9,3	44,5	19,5
Energy machinery	34,5	16,8	39,3	17,9	39,0	9,5	33,8	25,3	31,6
General machinery	35,8	27,1	49,1	33,4	44,7	7,5	45,4	37,9	28,5
Machine-tools	50,0	32,9	39,3	34,1	40,2	12,1	37,8	20,8	29,7
Measurement, control	31,6	21,3	29,9	22,4	36,0	10,0	17,1	38,8	27,8
Medical equipment	32,2	27,8	55,9	42,5	45,1	13,1	22,6	37,0	33,1
Metal products	46,4	31,1	43,0	34,8	45,1	12,5	43,8	36,1	27,5
Non-polymer materials	39,3	29,4	35,4	24,5	34,7	10,2	31,9	27,5	28,4
Optics	29,4	18,5	41,5	23,4	42,7	5,3	12,6	37,3	24,2
Pharmaceuticals	20,4	16,4	56,6	19,8	35,0	13,4	21,0	28,3	26,9
Polymers, rubber, man-made fibres	27,3	21,2	18,2	25,2	40,8	9,6	34,7	35,8	23,2
Special machinery	34,3	26,4	31,0	33,8	40,7	14,4	37,1	31,9	29,8
Telecommunications	35,2	11,9	8,6	8,6	29,3	4,1	7,8	10,1	21,4
Textiles, domestic appliances, food	36,5	21,2	33,3	30,7	32,8	11,7	25,1	36,6	29,9
Transport	39,5	12,2	31,4	14,6	40,3	5,3	43,3	18,9	22,9
Total	31,2	19,8	23,5	21,3	35,6	7,8	19,0	26,9	26,4

Source: EPO worldwide patent database (PATSTAT); Fraunhofer ISI calculations, update September 2008.

Table 2 contains the absolute number of patent applications by SMEs in the three years period 2003-2005, differentiated by 19 technological fields, and Table 3 displays the shares of SME's patent filings in relation to the total filings by field and country. Machinery and machine-tools as well as metal products are the technologies where the shares of SMEs are highest in almost all countries. On the other hand, the dominance of large multinational companies are obvious and most pronounced in the field of telecommunications in the two countries Finland and Sweden, where Nokia are and SonyEricsson are to responsible applicants for more than 90% of the applications. Similar results can be found for Philips in the case of the Netherlands, which dominates Electronics and Computers etc.

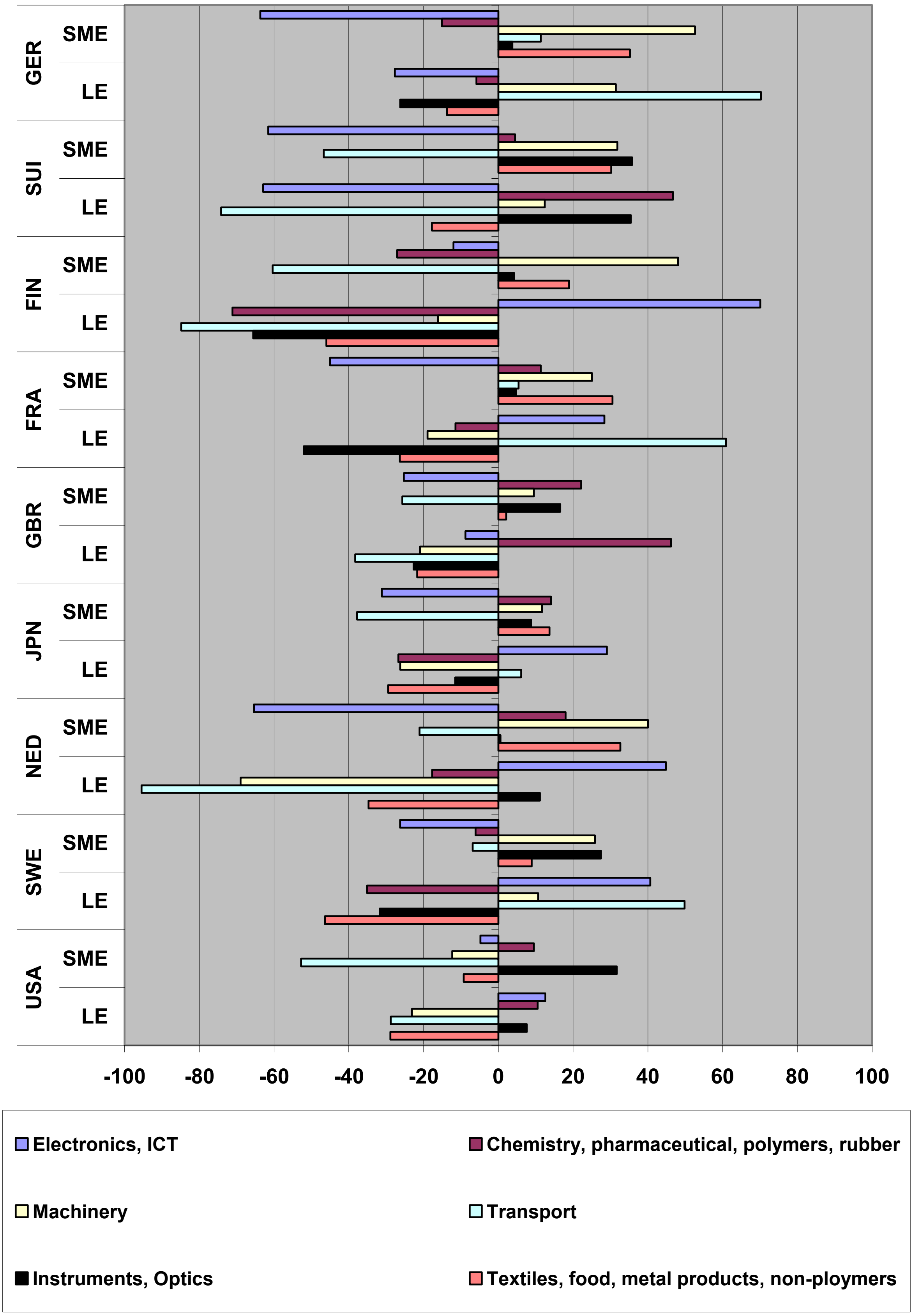
In some cases the differences between SMEs and large enterprises even result in different specialisation profiles of these two types of companies within the same country (see Figure 7). For example, German SMEs are specialised in Instruments and Optics, while large enterprises in Germany are strongly under-specialised which means that they are less active in this field than the world average. Textiles and food in Germany are relatively more often invented by small and medium-sized companies and not so much by large ones. In Finland and Sweden – this has already been stressed – the large multinational companies outperform the small and medium-sized enterprises in the Electronics and ICT area. But also in the USA, the large companies are specialised in Electronics and ICT, whereas the small and medium-sized companies show an activity level that is below the world average.

Table 4 gives a more differentiated picture of the specialisation profiles within the countries, using a classification of 19 fields. The picture becomes much clearer then. For example, the

Swiss small and medium-sized enterprises are focusing on Machinery and Machine Tools as well as Instruments (Measurement, Control, Medical Equipment) and the large companies are doing very well in Pharmaceuticals and Chemicals. Also in Germany the positive specialisation of the SMEs in machinery and machine tools is clearly visible. At the same time, the poor performance of the German economy in ICT is grounded on a strong negative specialisation of small and medium-sized companies and a less extreme, but still negative orientation of large companies. The absolute number of patents by small and medium-sized companies in the USA is considerably high, given the international or transnational orientation of the patents analysed here. As can be seen in Table 4, they especially well perform in the fields of Measurement and Control, Medical Equipment, and Pharmaceuticals – the latter reflecting also Biotechnology, Tissue Engineering, Synthetic Biology and related fields. Derived from these figures it can be said that the patents in the emerging and successful fields of the US economy are to a large extent also driven by small and medium-sized enterprises. It would be interesting to see if this also holds for Nanotechnology and Optical Technologies, which also belong to the emerging and enabling fields.

Further studies are necessary to dig deeper into the technological structure of patent filings by SMEs and it would also be interesting to see how they differ not only from large companies, but also from public research and university applicants, which are – as a matter of fact and a matter of their mission - more research oriented and maybe also more basic research oriented. At least the rough findings presented here suggest that small and medium-sized companies not only focus on low-tech areas like food and textiles and on special solutions and technologies for example in the area of machinery, but that they are also seeking new markets by conducting research and development in new, emerging and enabling areas.

Figure 8: Specialisation of SMEs and large enterprises by five technological areas in nine selected counties, 2003-2005



Source: EPO worldwide patent database (PATSTAT); Fraunhofer ISI calculations, update September 2008.

Table 4: Specialisation of SMEs and large enterprises in nine selected countries by 19 technological fields, 2003-2005

	SUI		GER		FIN		FRA		GBR		JPN		NED		SWE		USA	
	SME	**LE**	**SME**	**LE**	**SME**	**LE**	**SME**	**LE**	**SME**	**LE**	**SME**	**LE**	**SME**	**LE**	**SME**	**LE**	**SME**	**LE**
Audio-visual electronics	-65	-58	-80	-70	-42	61	-27	45	-36	-18	-49	54	-65	69	-51	-28	-30	-21
Basic chemicals, petroleum products	-17	29	-21	18	-38	-75	-8	-26	-4	62	18	-3	-5	24	-43	-67	-7	17
Computers, office machinery	-64	-73	-75	-49	-37	35	-54	-6	-19	5	-27	36	-62	66	-27	-51	12	22
Electrical machinery, energy	-35	-6	-2	30	-31	-47	-2	27	-23	-54	16	29	-56	-26	-28	-68	-9	-17
Electronic components	-61	-82	-33	-22	-38	-88	-73	-19	-67	-34	17	58	-44	45	-66	-97	-31	17
Energy machinery	-15	-19	37	63	-57	-92	-19	14	-4	12	9	-8	-57	-97	12	30	-16	-16
General machinery	30	17	49	10	78	13	35	-29	13	-23	-19	-17	62	-67	32	-32	-16	-22
Machine-tools	58	-32	75	24	26	-60	27	-30	-35	-51	43	-3	-12	-92	32	63	-23	-29
Measurement, control	46	50	21	12	12	-27	-4	-17	18	4	15	-17	-15	1	30	-29	13	-1
Medical equipment	47	42	1	-66	0	-94	23	-90	29	-37	-2	-61	9	-21	44	-15	56	22
Metal products	42	-49	70	13	-3	-83	56	-15	30	-60	-30	-79	43	-82	46	-3	-33	-46
Non-polymer materials	19	-34	43	-21	33	-29	13	-10	-28	-51	39	11	2	-74	-10	-31	-6	-10
Optics	-58	-58	-41	-40	-6	-69	-29	-34	-27	-58	18	58	11	63	-46	-79	-25	-13
Pharmaceuticals	4	55	-37	-35	-16	-98	6	-18	39	58	9	-60	-4	-39	16	7	31	7
Polymers, rubber, man-made fibres	22	47	18	7	-34	-6	34	11	14	-23	18	-4	54	-39	-11	-78	-18	8
Special machinery	41	35	51	15	52	18	37	-33	26	-34	17	-55	61	-34	27	-15	-4	-27
Telecommunications	-70	-80	-74	-26	23	90	-63	49	-31	-4	-57	8	-74	14	-17	84	-16	21
Textiles, domestic appliances, food	32	2	0	-20	15	-43	29	-43	8	7	5	-45	44	5	2	-74	-4	-36
Transport	-47	-74	11	70	-60	-85	5	61	-26	-38	-38	6	-21	-95	-7	50	-53	-29

Source: EPO worldwide patent database (PATSTAT); Fraunhofer ISI calculations, update September 2008.

4. International and German Co-patents

In this section we examine those patents invented by a group of multinational inventors. More exactly speaking, we deal with internationally co-invented patents whose inventors reside, at the time of patenting, in at least two different countries (henceforth, we call this class of patents "international co-patents" or just "co-patents"). International co-patenting takes several different forms. First, in the form we dubbed "within-organization international collaboration," inventors affiliated with a multinational company but located at different national branches collaborate for an invention. Co-patents in this case would indicate some amounts of cross-border knowledge flows. However, knowledge spillovers outside the company would be limited. Also, patterns of co-patenting would significantly depend on the patterns of international collaboration within multinational companies. The second form of co-patents ("between-organization international collaboration") refers to the cases in which inventors with different organizational and national affiliation collaborate for an invention. This case would represent more fluid form of international division of innovative labour and have possibly larger spillover effects. Either case, however, represents a certain level of international division of innovative labour and knowledge transfer among countries. Considering increasing complexity of technology and importance of global markets for the contemporary firms, international research networks will be crucially important for the national and firm-level competitiveness. Studying international co-patents will reveal an important facet of this phenomenon.

We analyze trends and aspects of international co-patents at country level. The different effects and policy implications from different organizational structures of international co-patents is beyond the scope of this study. Our main focus is German co-patents (so to speak, a patent having at least one German inventor and at least one inventor affiliated with other countries) and their relative positioning in the playing field of international co-patents. We will illuminate German co-patents from several different angles including temporal evolution, technological composition, and partner characteristics. Also, in order to locate the position of German co-patents in the scene of broader context of international co-patents, we overview the trends and characteristics of international co-patents and compare German co-patents with them. After examining both German and international co-patents with a set of multifaceted analytic lenses, we derive lessons and implications for co-patenting in general and for Germany's co-patenting, in particular.

This section is organized as follows. We first present the results of analyses on overall trends of international co-patents and a series of detailed analyses of them especially focusing on comparative perspectives. Then, we proceed into the German co-patents and discuss some policy implications.

4.1 Data sources

For most of analyses in this section, we use two databases: all published patent applications filed directly in the European Patent Office (EPPATENT) and all published PCT applications (WOPATENT), both provided by a French company, Questel-Orbit. We aggregated search results from both databases. Considering that EPO quite well represents the patents from European countries (Frietsch et al. 2008; Frietsch/Schmoch 2006) and that PCT filings rapidly grow over the globe, our data will well depict the trends and patterns of transnational patent filings, especially well reflecting European patents and non-European patents targeting for European markets. However, because we did not include a huge chunk of patents filed in the other two largest patent offices (i.e. US Patent and Trademark Office and Japanese Patent Office), our data may not give a reliable picture on patented technology targeted only for US or Japanese markets.

For comparative analysis, we examine Germany plus 12 countries. They include 10 top patenting countries with seemingly close relationship with Germany's patenting (i.e. the United States, Japan, Great Britain, France, the Netherlands, Italy, Canada, Sweden, Switzerland, and Finland) and 2 rapidly-growing countries (i.e. China and South Korea). Collectively, patents from these 13 countries account for 92.5% (=181,150/195,926) of the world patents filed in 2006. Also, this mix of technologically advanced countries and rapidly-growing countries will give a good comparative view on the German co-patents.

Keeping in mind this advantage and disadvantage of our data sources, we will proceed into analysis of international co-patents in the next part.

4.2 International co-patents – Overall trends

Growing international co-patents

International co-patents have rapidly grown since 1990s. The number of co-patents in 2006 hits 20,102 which has almost quintupled since 1991 and doubled since mid-90s. The compound annual growth rate (CAGR) of total co-patents of 13 countries between 1991 and 2006 is 11.0% (Table 5, the last column) exceeding the annual growth rate of total world patents (7.2%) for the same period. For all selected countries except Japan, Korea, and China, the growth of co-patents exceeds the growth of total patents for a set of multiple periods compared (Table 5). Although Korea and China have rapidly increased their co-patenting (about 20% annual growth for Korea and about 30% for China), their growth in total patents (about 30% for Korea and about 40% for China) have much more rapidly increased for the designated periods. Japan has a different story. While the growth rate of Japan's transnational patent filings slow down in the recent years compared to other countries, its growth of international co-patenting has even more decelerated. Also, Japan ranks in the lowest position in terms of growth of international co-patents. This indicates that Japanese innovation system is a relatively closed one.

For the United States and other European countries, the growth of co-patents is in decreasing trends although not as rapidly as the growth of total patents. Among European countries, rapid growth of Sweden and Finland is notable. They have a medium level of co-patent share currently (around 15%. See Figure 9) but if this growth trend is maintained their co-patent share will approach the current Swiss level (33%) in 12 years' time for Sweden. Swiss and Canada have a strong presence of co-patents and shows high growth rate. Compared to other countries, the growth rate of German co-patents was slightly above the average in the early 90s but went slightly below the average in recent years.

Table 5: Compound Annual Growth Rate (CAGR) of international co-patents for selected countries

Period	US	JP	DE	GB	FR	CH	CA	SE	IT	NL	FI	KR	CN	Tot
1991-1998	16.7	11.7	16.2	13.3	15.0	12.2	17.5	19.7	15.1	15.4	25.2	21.7	24.1	15.6
1998-2002	7.2	5.3	7.7	7.6	10.5	10.1	7.9	-0.5	6.9	8.7	10.7	20.3	30.2	8.0
2002-2006	5.5	0.7	5.2	1.9	6.5	7.9	7.1	13.0	8.0	2.4	8.8	19.5	28.6	6.2
1991-2006	11.1	7.0	10.9	8.6	11.5	10.5	12.0	12.2	11.0	10.0	16.7	20.7	26.9	11.0

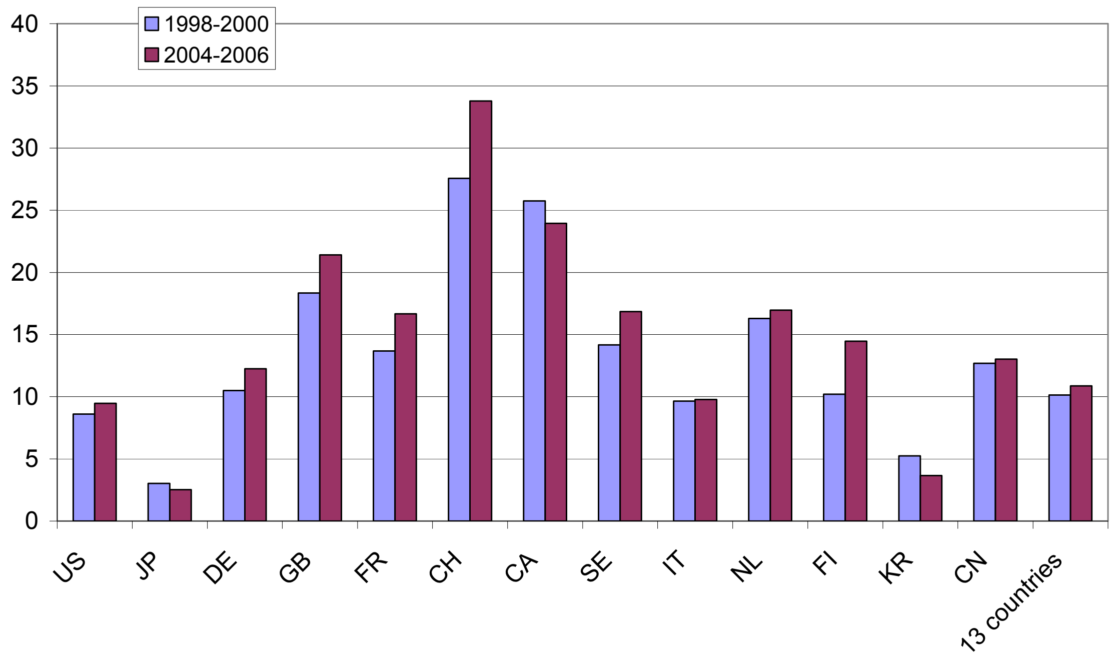
Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Country heterogeneity

The growth of the co-patents is synchronized, to some extents, with the growth of total patents. Figure 9 shows the proportion of co-patents in the total transnational patents by each country for two periods: 1998-2000 and 2004-2006. This figure clearly shows that the share of co-patents has increased in all but three countries (Japan, Canada, and Korea) between two periods. In total 10% of patents from these countries filed during 1998-2000 are co-patented and 11% during 2004-2006.

Among the analyzed countries, Switzerland has the highest share of co-patents. About one-third of Swiss patents filed in recent three years have at least one inventor from other countries. Canada and Great Britain stand next, co-patenting more than 20% of their patents. Germany, Italy, and United States stand at around the middle, co-patenting between 9% and 12%. Japan and Korea co-patents less than 5%. The reasons behind co-patenting may vary across countries. For example, geographical and cultural proximity to strong countries in terms of patenting may affect the higher share of Canada's (next to the US) and Swiss's (next to Germany and France) co-patents. In other cases, presence of many global research centres may drive co-patents of Great Britain, Swiss, and the Netherlands. Also, strong presence of sectors prone to international collaboration (e.g. pharmaceutics) may affect the rate of co-patents. We will give a detailed look at the technology composition of co-patents below.

Figure 9: Co-patents share of national filings of patents for selected countries

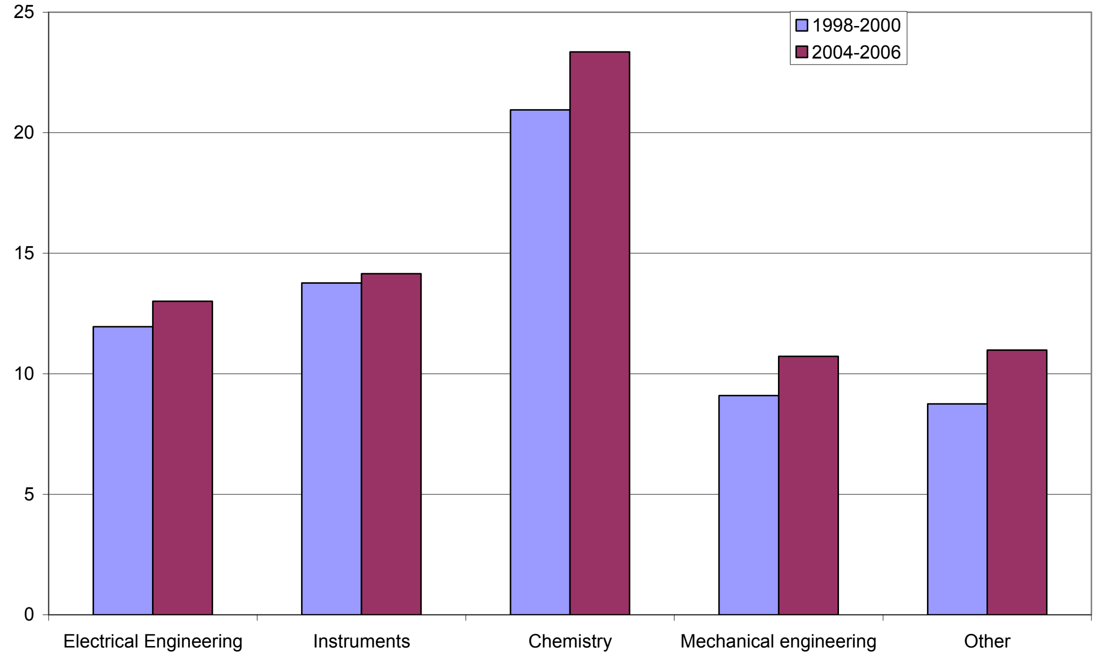


Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Chemistry: a field of international collaboration?

Next, we examine the co-patents by technology field. We calculated the co-patent share of total patents within each of 5 technology classes. The average share over 13 countries is graphed in Figure 10. During the recent three years, while about 23% of chemistry patents have multinational inventors, only about 11% of mechanical engineering patents have multinational inventors. Instrument and electrical engineering co-patents mark around 13%. Across all 13 countries, chemistry co-patents show the highest proportion. Strong presence of multinational pharmaceutical and petrochemical companies and their active international collaborative research activities would have led to this flourishing chemical co-patents. Bearing in mind the technology heterogeneity of the propensity of international co-patents, we take a closer look at the interactive effects of technology and country on co-patents.

Figure 10: Average shares of co-patents for 13 countries by technology field



Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Why co-patenting?

In order to isolate the effect of technology on the propensity of co-patenting, we devised a summary index called "Technology Quotient of Co-patenting (or TQC)." TQC calculates the technology share of co-patents of a country normalized by the technology share of the country's total patents[4]. This indicator isolates the technology effects from country effects on co-patenting. The calculations are presented in Table 6. Confirming the conjecture drawn from the overall picture above, chemistry patents show disproportionately more co-patents across all countries. Patents classified in Mechanical engineering and Other show disproportionately lower level of co-patenting. The rest two fields (Electrical engineering and Instruments) vary by countries.

4 The Technology Quotient of Co-patenting (TQC) is defined as:

$$TQC_{kj} = 100 * \tanh \ln [(C_{kj}/\Sigma_j C_{kj})/(P_{kj}/\Sigma_j P_{kj})] . \qquad (1)$$

with C_{kj} and P_{kj} indicating the number of co-patent and patent applications, respectively, of country k in the technology field j. Positive values point to the fact that the technology has a higher weight on co-patenting in the portfolio of the country. Negative values indicate co-patenting specializations below the technological strength of the country. This indicator allows the assessment of the strength of co-patenting in a technology field in a country relative to technology specialization of the country.

Table 6: Technology quotient of co-patenting (2004-2006) for selected countries

2004-2006	Electrical Engineering	Instruments	Chemistry	Mechanical Engineering	Other
USA	-14.5	-17.2	30.2	-11.1	-19.2
JPN	-21.8	-11.7	49.4	-50.9	-25.7
GER	-3.7	3.8	45.6	-47.1	-32.4
GBR	0.8	-10.0	25.6	-36.3	-28.7
FRA	-33.5	-1.2	49.6	-45.5	-35.3
SUI	-20.0	-20.6	39.1	-38.3	-29.2
CAN	-14.7	2.4	26.2	-12.5	-31.2
SWE	5.5	-16.0	45.3	-52.2	-27.0
ITA	10.6	22.0	39.8	-47.2	-44.3
NED	-60.8	1.8	53.6	-2.3	-30.9
FIN	8.9	-49.6	48.0	-63.2	-34.2
KOR	-2.9	31.0	36.0	-6.7	-79.5
CHN	-33.9	20.3	56.0	-13.2	-8.8
Average	-13.8	-3.5	41.9	-32.8	-32.8
Std. Dev.	20.5	21.2	10.0	20.7	16.3

Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Then, a natural question arises: what makes the technology heterogeneity of co-patenting? Will an inventor seek foreign co-inventors who have complementary technology? If co-patents would occur more between countries who have complementary technology to each other, then a country specialised in a particular technology will face higher in-bound international collaboration demands and lower out-bound collaboration demands. Because co-patenting does not give us any directional information in collaboration, this seems to tell us nothing about the relationship between the strength of technology specialisation and the propensity of co-patents. However, while in-bound collaboration demands would be distributed over several countries who are specialised in a technology, outbound demands can be captured in entirety in country profile of co-patent data. Under this behavioural assumption, we predict a reciprocal relationship between a country's specialisation of a particular technology area and the propensity of co-patents of the country in that technology area. For example, suppose a country A is weaker (in terms of the technology share of patents) than other countries in technology X and stronger in technology Y. Then the co-patenting rate in technology X will be disproportionately lower and the co-patenting rate in technology Y will be higher than the average co-patenting rate of the country.

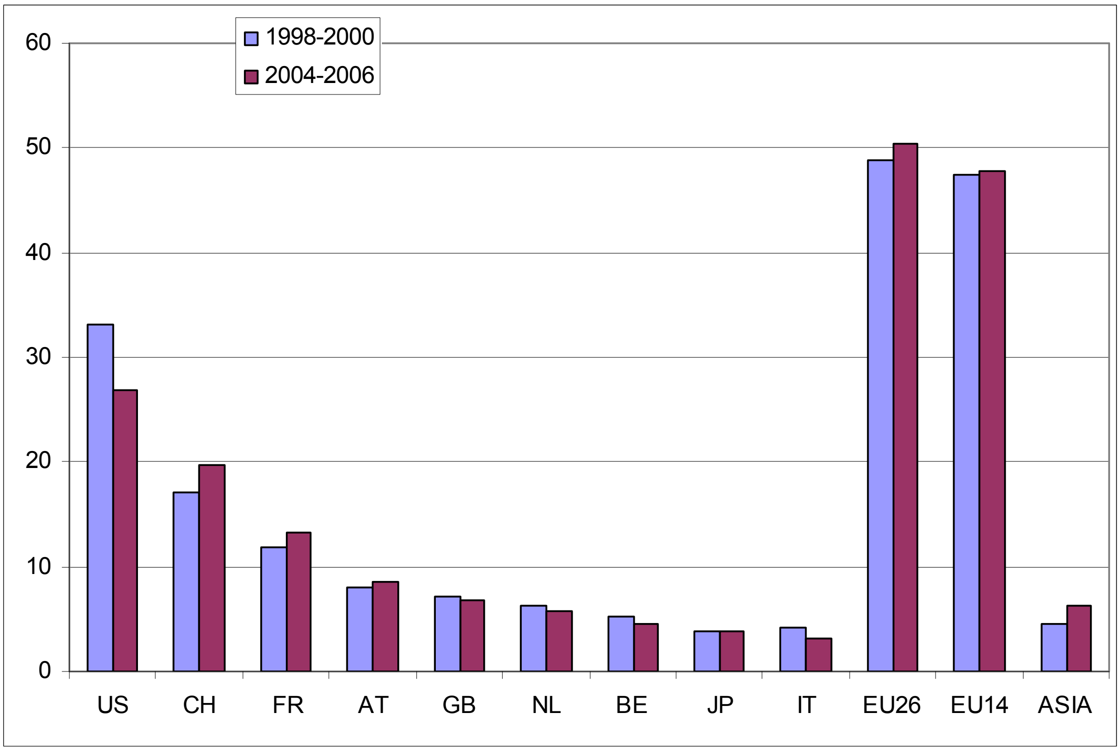
In order to examine this question, we regressed TQC calculated for each year from 1991 to 2006 on country's technology specialisation index with technology and year fixed effects controlled (N=1,035). The model fits well with our data ($F(20, 1014) = 116.84$, $Prob > F = 0.0000$). Collectively, the model explains about 70% of variations in our dependent variable, TQC. We found statistically significant and negative association between TQC and the country's technology specialisation index (beta=-.298; t-statistic=-12.85). Therefore, we conclude that the rate of co-patenting in a technology field of a country is higher for a field in which the country is weaker and lower for a field in which the country is stronger. This finding implies the positive effects of international co-patents on strengthening technological competitiveness of a country and provides a rationale for such policies that can promote international collaboration.

4.3 German co-patents

Partner profile

The most favourite partner country of Germany's co-patenting is the United States. About 27% of German co-patents are made with the United States during 2004-2006 period followed by Switzerland (20%) and France (12%). Also, 48% of German co-patents were made with countries in EU-14 (i.e. FR, AT, GB, NL, BE, IT, SE, ES, FI, DK, LU, GR, IE, PT). In total, German co-patents with US and countries in EU-14 account for more than two-thirds of total German co-patents. Co-inventing with 3 Asian countries (i.e. Japan, South Korea, and China) explains only 6%. Comparing the country share of German co-patents between two time periods (1998-2000 and 2004-2006), the share with US has dropped by 5 percentage points while the share with European and Asian countries has increased. This indicates that co-patenting partners of Germany has diversified. However, some of this trend would be explained by decreasing share of US patents and increasing patenting activities of other countries.

Figure 11: Distribution of partner countries of German co-patents



Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Technology profile

As in the other countries, chemistry patens show disproportionately higher rate of co-patenting in Germany (Figure 12 (b)). Consistent to the claims made above, German co-patents show lower rate in Germany's strong area (i.e. Mechanical engineering and Other) and slightly higher rate in weak area (e.g. Electrical engineering and Instruments) (compare panel (a) with (b) in Figure 12). However, because Germany has a weak presence in electrical engineering and instruments, co-patenting in these areas show disproportionately lower rate compared to the distribution of world patents over technology area (Figure 13). On the other hand, in Transport technology, in which Germany maintains strong presence, German co-patents show lower proportion than the share of German patents but higher proportion than the share of world patents in this field.

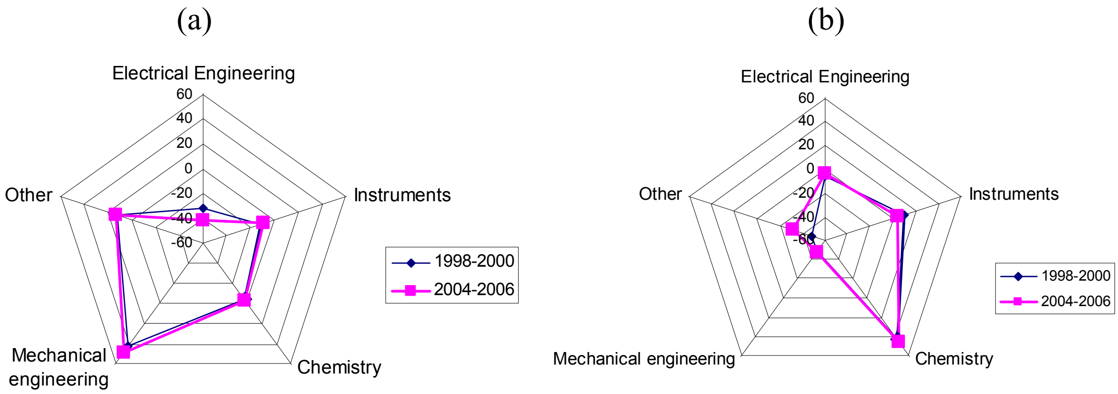
Finally, we examine in which technology field Germany co-patents with each country. Similar to TQC, we devised an index that measures relative strength of co-patents by technology area with individual country (=the technology share of German co-patents with respective country divided by the technology share of German co-patents with all countries). This index indicates the relative strength of German co-patenting in a particular field with individual countries compared to overall co-patenting pattern. The calculations of this index for top three countries (United States, Switzerland, and France) are presented in Table 7. Results show that, in Electrical engineering, Germany prefer to co-patent with the United States who is strong in this field. In Instruments, while United States and Switzerland are strong, France is weak, which aligns to the pattern of technology strength of these countries.

Table 7: Co-patenting specialization w.r.t individual country

2004-2006	Electrical Engineering	Instruments	Chemistry	Mechanical engineering	Other
USA	11.2	20.0	-8.1	-2.8	-25.7
SUI	-51.4	22.8	18.2	-21.3	-3.7
FRA	-17.4	-30.0	14.5	2.4	-3.3

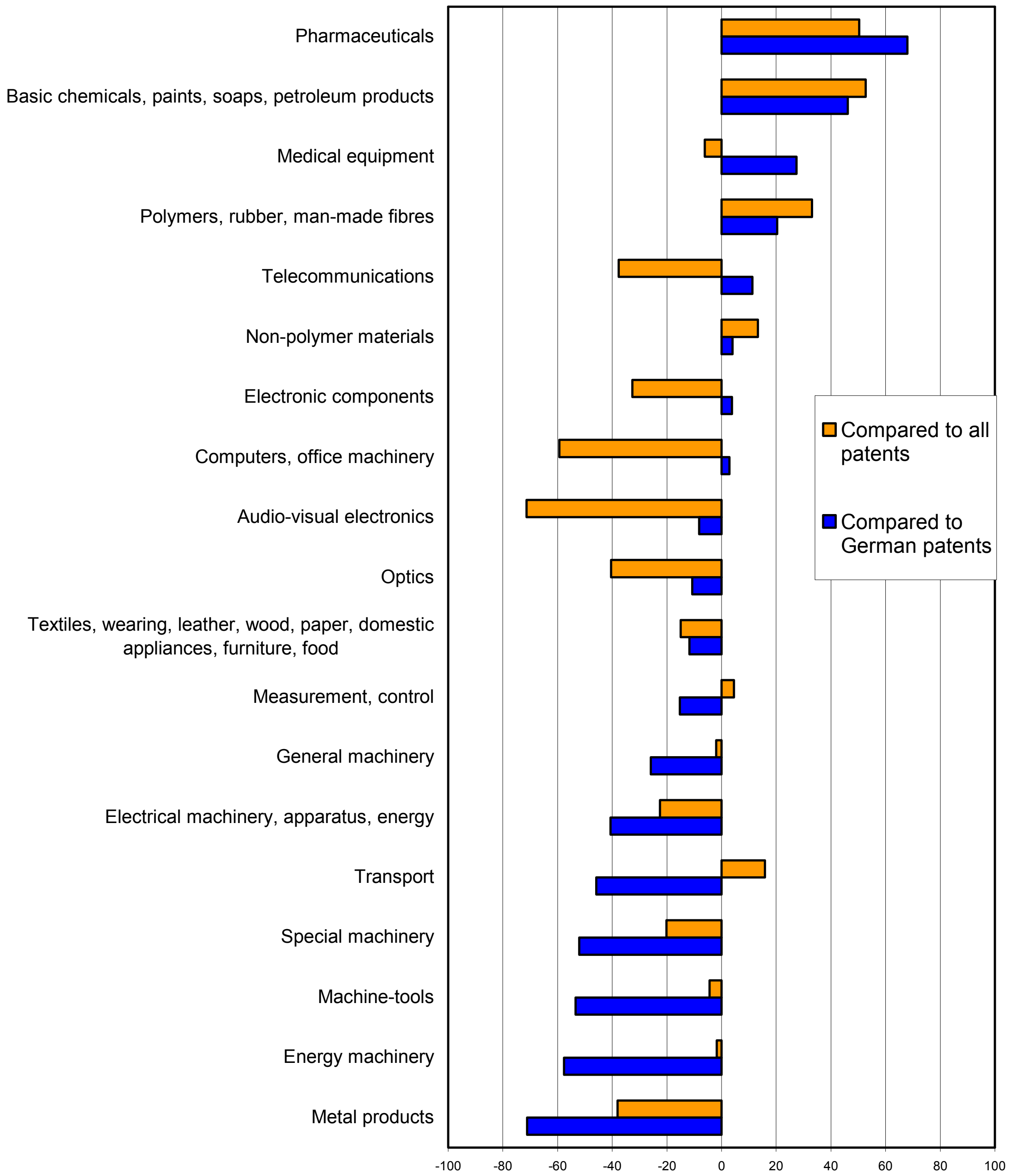
Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Figure 12: Specialisation index of German patents (a) and co-patents (b)



Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

Figure 13: Specialisation profile of German co-patents (2004-2006)



Source: Questel-Orbit: EPPATENT, WOPATENT; Fraunhofer ISI calculations, update September 2008.

5. Summary and Conclusion

In this study, we compared the profile of German Transnational Patents with the patenting profiles of other countries from several different angles. Germany is a stronghold in international patenting in terms of the absolute number of filings (ranked the third only after the United States and Japan) and the number of filings per employee (ranked the fourth after Swiss, Sweden, and Finland). However, its growth rate is lower than the top-patenting countries and even below the EU average. This indicates that comparative technological advantage of Germany may be debilitated in the future. In order to revamp technological advantage of Germany, tracking the situation of fast-growing countries such as Korea and China would help.

Probably more serious problem for German innovative capabilities is its weakness in fast-growing, technology-intensive industries such as ICT and biopharmaceuticals. While Germany is very strong in patenting in moderately technology-intensive sectors such as machinery and automobile, its technological presence in terms of international patent filings are very weak in Electronics, ICT, and biopharmaceuticals. Moreover, patent filings from small and medium-sized enterprises in these sectors are much weaker.

As a remedy to this problem, international collaboration can be a candidate solution. We showed that international co-invention occurs more frequently in the weaker technology areas. This indirectly indicates that international collaboration would help a country to strengthen its currently weak technological capability. International co-invention has been growing faster than the growth of patenting. Also, in rapidly-growing fields such as chemistry and electronics, international co-invention is more frequently observed. Therefore, policy instruments that can promote international research collaboration and attract multinational companies in these growing fields to build their research centres in Germany would help Germany advance into a major technology player in these fields. In addition, to bolster technological capabilities of small and medium-sized enterprises in these growing, technology-intensive sectors, promoting interorganizational technology transfer, especially from universities, and institutionalizing venture capital would be essential.

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