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The internationalisation of international co-inventions

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1. Introduction

Patents are a vested right to grant a temporary monopoly on the use of a certain technology or technological solution. Patents are one – among others – output of R&D processes and can therefore be interpreted as an innovation indicator of technologically oriented research and development activities. However, they are also a promise to the future as they are input to future market activities – at least on technology oriented markets.

The nationality of patents can be measured in three dimensions: 1) The country of the applicant, 2) the country of the inventors and finally 3) the “nationality” of the offices where the application is filed. The latter approach is the core of this paper with a special focus on internationally co-invented technologies.

A very frequently used approach (inventor dimension) to analyse international knowledge flows and collaborations is the use of international co-patents (Ejermo, Karlsson 2006; Frietsch, Schmoch 2006; Hagedoorn et al. 2003; OECD 2008). However, co-patents also reflect the organisation of research teams within MNEs, which account for the majority of patents as well as for the majority of international co-patents. In any case, motives to collaborate are the access to complementary knowledge or the access to research facilities, instruments or results – so co-patents are capable of international knowledge flows (though the direction of these flows cannot be detected).

In Frietsch and Jung (2009) we differentiate between two forms of international co-patenting. On the one hand, "within-organization international collaboration" occurs where inventors affiliated with a multinational company but located at different national branches collaborate for an invention. In this case co-patents indicate some amounts of cross-border knowledge flows while knowledge spill-overs outside the company are limited. On the other hand, "between-organization international collaboration" refers to co-patents where inventors with different organizational and national affiliation collaborate for an invention. This case represents a more fluid form of international division of innovative labour. Co-patents have possibly larger spill-over effects. Either case, however, represents a certain level of international division of innovative labour and knowledge transfer among countries. The results of the empirical analysis proves the increasing relevance of co-patents and hence the increasing necessity to collaborate internationally.

This differentiation only refers to the inventor level, while other scholars have also included the applicant dimension (e.g. Grupp 1997; Grupp and Schmoch 1992; Hullmann 2001), who are then able to define four distinct cases of international co-patents, namely (1) domestic inventor / foreign applicant; (2) domestic applicant / foreign inventor; (3) domestic and foreign applicants; (4) domestic and foreign inventors. In this paper we only focus on case four as international collaborations and knowledge flows are in the core of this study.

The same distinction has been used by Guellec and van Pottelsberghe (2001; 2004) for their analyses, where they have suggested to analyse combinations of the first two dimensions by looking at international ownership (applicant dimension) of national inventions (inventor dimension) as well as national ownership of international inventions (see also OECD 2008). Edler et al (2003) have applied a similar approach to analyse the internationalisation of research in Multinational Enterprises (MNEs) in Germany.

The share of co-assigned patents is relatively low, relative to co-inventions, even though some discussion can be found in the literature that there is an increasing trend to joint ownership and exploitation of inventions in certain areas – for example in biotechnology (Pyka and Saviotti 2002), but example of the automobile and electronics industry can also be found in patent databases.

Co-patents are more and more used to examine links between industry and public research institutions. For example, Van Looy et al (2003) analyse the co-patenting activity between universities and public research institutes on the one hand and industrial companies on the other. This type of collaboration increases in relevance as public research organisations are managing their IP actively and seek for application of their knowledge and inventions. While the Bayh-Dole Act fostered such a rent seeking already since the 1980s in the USA, European countries now more and more shift their attention towards this path of technology transfer form public research to industry. For example, the abolishment of the so called „Hochschullehrerprivileg“ (Professor's privilege) in Germany and the installation of exploitation agencies (Patentverwertungsagenturen) aims at exactly this idea. However, Lissoni et al. 2007 recently have been able to show that also in Europe public research involvment in patenting is on a similar level like in the USA and also Schmoch (2007) and Schleinkofer (2008) have been able to show this for Germany, too.

Patel and Frietsch (2007) have analysed the patent applications of a selected set of MNEs to examine, if the inventor country can be used as an indication of R&D activities at the micro level. Next to the feasibility of this approach the study showed considerable differences in the internationalisation (inventor dimension) between Asian and Western enterprises (applicant dimension). Furthermore, some connection between inventor countries and filing countries (office dimension) became obvious.

The main questions to be addressed by this paper are:

1) Are internationally co-invented patents targeting more international markets (defined by the auspices of patent offices)?
2) Are internationally co-invented patents targeting more important markets like USA, Japan, Germany, UK, France, China etc.)?

Against the above mentioned background this paper analyses the filing structure of internationally co-invented patent families. International co-inventions are patents where at least two inventors from two different countries were involved. A patent family is the set of patents that share the same priority document (worldwide first application) – this is the simplest definition of patent families.

The paper is organised as follows. Section two offers a discussion of patents as an innovation indicator. In section three the methods and data sources are presented before section four depicts the overall trends in international co-patents. The core of our empirical work is presented in section five before the paper concludes with a summary.

2. Patents and International Co-patents

2.1 Patents

Patents are one of the most important innovation indicators to assess the technological competitiveness of innovation systems (national, regional, or sectoral), as they are one possible – among others – output of R&D processes (Freeman 1982; Frietsch, Schmoch 2006; Grupp 1997; Grupp 1998). Though patents are only applicable to technological innovations – and even here they cover only a fraction of all innovative activities – they can be interpreted, on the one hand, as an output indicator of the R&D process. On the other hand, patents also point to the future, with the prospect of implementing the technologies and opening new markets or gaining new market shares with new products. Especially in high-technology areas, patents can help to measure present and future competitiveness of companies, sectors, or economies (Frietsch, Schmoch 2006; Schmoch 2004). A major reason for the high esteem of patent indicators are the manifold information elements in patent documents and in particular their very detailed classification allowing for analysis at low levels of aggregation and of a tailor-made match of patent analyses to specific topics. Another reason for their popularity is the easy access to patent data due to the free offer of patent databases in the internet by some large patent offices. Thus it is possible to generate large datasets for statistical analyses without conducting costly interviews or surveys.

Patents are legal documents defining the protection area referring to a specific technical invention. In this regard they are indicators of new technology and technological progress. At the same time they are relevant instruments for safeguarding markets and therefore they are also indicators of market interest. Patent offices administer patent applications, they examine the claims and they grant a temporary monopoly for the exclusive use of patents. But any patent office can only do this in the territory of its responsibility. If patent protection is achieved in Germany and France, for example, the technology can still be used freely in the UK, in Spain, in Italy etc. Therefore, more than one patent office is approached by an applicant if a broad coverage is intended. A patent family is the set of patents that share the same priority document (worldwide first application) – this is the simplest definition of patent families. In the smallest case this family only consists of the priority document itself.

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. These are the reasons they are so suitable for analyses of technical progress and technological competitiveness (Frietsch, Schmoch 2006; Nesta, Patel 2004; Schmoch, Hinze 2004).

A patent application has to satisfy at least three criteria: novelty, inventive step and industrial applicability. The criterion of novelty implies not only novelty for a national system or for the applicant, but novelty on a world-wide scale. Furthermore, any publication – for example, in a scientific paper or contribution to a conference – or any implementation of the invention in any product or process is considered prior art and inhibits patent protection. The second criterion – the inventive step[1] – 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.[2] The third requirement of industrial applicability is generally fulfilled, because of the considerable costs of patent applications which are only spent with a realistic market perspective.

Patent documents provide – as a side effect of the application process – a large number of information that can be used for empirical innovation studies. Among these vast information are very detailed classification schemes, timing of procedural steps, but especially detailed information on the application (owner), the inventor(s), and – in the case of a suitable database – information on the markets/offices, where patent protection is sought by the applicants. The latter data is of crucial importance to this study as the nationality of patents can be measured in three dimensions, namely the country of the applicant, the country of the inventors, and finally the "nationality" of the offices where the application is filed.

2.2 International Co-patents

International co-patents (henceforth "co-patents") are defined as any patent where inventors from at least two different countries are registered. In consequence, this definition does not only cover co-operations of different companies and research institutes, but also such kinds of innovations are encompassed that arise from globally acting "multinationals". For instance, if researchers from different international research sites of one company join in the production of a patent, this co-operation is included. One goal of this approach is to measure international "knowledge flows" for the assessment of the "globalisation" of applied research and development. This definition also entails internationally co-invented patents whose inventors reside, at the time of patenting, in at least two different countries, but which do not necessarily also hold the nationality of that country.

3. Methodology of the Patent Analyses

The "EPO Worldwide Patent Statistical Database" (called PATSTAT) is a database, which has its origins in the internal database DocDB of the European Patent Office (EPO), which the EPO needs for its examiners to search for prior art and to do their examination, especially of worldwide novelty. DocDB is not primarily compiled to serve statistical needs, but to serve procedural needs stemming from the application procedure and the patent law. Patent statistics are only a side effect of these procedural requirements. DocDB, and therefore also PATSTAT, covers patent applications from more than 80 offices all around the world, storing information on bibliographic details of the applicants, the inventors and – of course – the patents as such for example like date of first filing (priority), date of filing to the office, legal status etc. It only contains records of published patent filings. This means that not all applications – for example to the EPO – are provided but only those which were published. To put it in other words, only applications that are maintained until the publication of 18 months after priority filing are stored. Applications that are

1 In US patent law, the corresponding requirement is called "non-obviousness".
2 See Art. 56 of the European Patent Convention (EPC): http://www.european-patent-office.org/legal/epc/e/ar56.html#A56.

withdrawn or rejected – for whatever reason – are not covered by this database. The share of withdrawn or rejected patent filings may sum up to nearly 50% of the published filings. Furthermore the United States Patent and Trademark Office (USPTO) only published granted documents until 2001 and even today only a fraction of all applications to the USPTO are published after 18 months as the applicants may avoid publication by certain means (Schmoch 2009). For example a pure national application to the USPTO does not have to be published after 18 months. The largest share, especially of US-American inventors, does not file an international application and is therefore allowed to choose the postponed disclosure of their technology.

A patent family is the set of patents that share the same priority document (worldwide first application) – this is the simplest definition of patent families. In the smallest case this family only consists of the priority document itself. This definition has its strength in its simplicity, though it excludes all those patent documents with missing priority information, circular referencing or mistaken priority numbers. However, about 90% of all patent documents fit this definition. In this study we use the so called INPADOC definition of patent families, which is already implemented in PATSTAT, and which groups all patents which share the same priority (under the Paris Convention) as well as all divisional or continued applications that are related to these priorities.

3.1 Data and sample

In order to examine the internationalization of patenting in terms of patent authorities and inventor countries, we need a comprehensive set of patent data satisfying the following two conditions. First, it should cover patent applications from a wide range of national and regional patenting offices. Because we are interested in the breadth of international filings, we need to look at the patent filings in some “minor” patent authorities as well as important authorities such as USPTO, EPO, or JPO. Second, a reliable and consistent definition of patent family should be applicable. Given the fact that the essentially same technology may be filed with different scope, title, and identification number in different patent authorities, it is crucially important to identify, in a reliable and consistent way, which patents filed across multiple authorities can be regarded as “same”.

“EPO Worldwide Patent Statistical Database” (henceforth, PATSTAT) satisfies these two essential conditions. Moreover, PATSTAT provides a rich set of detail bibliometric information regarding patent applications, grants, and citations. The latest version covers 54,371,495 patent publications collected from 81 patent authorities worldwide. We constructed an analysis sample based on the latest available version of PATSTAT (“EPO Worldwide Patent Statistical Database - September 2008”).

Our definition of patent families is based on INPADOC patent family defined by EPO and available in the latest PATSTAT database. The INPADOC family links all applications related by Paris Convention priorities and, additionally, links “technically related applications (where the relationship is attributed by patent examiners)” and divisional or continued applications (European Patent Office, 2008). This INPADOC family (henceforth, “patent family”) is our unit of analysis.

We built the sample according to the following procedures. First, we identified all patent families in 4 different years (1990, 1995, 2000, and 2005) in terms of the filing year of the first priority application. Then, we collected all the patent applications referred by these families and aggregated them at family level. In doing so, we dropped non-patent applications (such as “Utility Model”) and a part of patent applications which do not have any information on inventor countries or technology class. There are two problems using the family from the PATSTAT. First, there is a huge drop of families due to the lack of information on inventor countries (more than 50%) and, more seriously, the majority of the dropped patents (around 90%) came from a particular authority – the Japanese Patent Office (henceforth, JPO). Second, during the analysis period, two patent authorities (China and Korea), in particular, show an enormous increase in national filings, probably stemming from country-specific reasons. To avoid unexpected bias due to the omitted observations from the JPO and country-specific inflation of cases related to China and Korea, we choose to focus on more complete and stable sources – EPO, USPTO, Germany, the Great Britain, France, and PCT filings. The sample of the families are, therefore, filed in at least one of the above 5 authorities or filed as a PCT in any patent authorities. This restriction cut off 34% of observations. The final sample is composed of 860,222 families with more than three millions of patent applications. Sample statistics are presented below in Table 1.

3.2 Variables

3.2.1 Dependent variables – degree of internationalization in exploitation

Number of filing authorities

As a measure of internationalization in exploiting patented inventions, we used the number of different authorities in which patents in the same family were filed. We regard PCT filing as a separate independent authority regardless of its original filing authority.

Indicators of filing authorities

Then, we examine the effects of the covariates on the propensity to file in two internationally-oriented authorities - EPO and PCT. Indicator variables, dauth_EP and dauth_WO are created by coding 1 if a family includes at least one patent filed in EPO or as PCT, respectively. In addition, another variable, big2all, indicates whether a family is filed in EPO *and* as PCT.

3.2.2 Independent variables – degree of internationalization in invention

Internationalization of invention process is measured by an indicator variable, dcoinv, coded 1 if a family has two or more distinct inventor countries. The inventor country is identified from the country of residence of inventors at the time of patent filing. In order to examine the temporal effects, we interacted international co-invention dummy with priority years and generated three interaction terms – iy95dcinv, iy00dcinv, and iy05dcinv which indicate interaction of co-invention with priority year 1995, 2000, and 2005, respectively.

3.2.3 Controls

Filing strategy of patents may vary by the inventor countries. We control the country-specific effects by including a set of inventor country dummies. They are the following 8 key countries – United States, Japan, Germany, Great Britain, France, Switzerland, China, and Korea.

By definition, patent families are composed of one or more patent applications. The number of filing authorities must be related with the number of patent applications. For example, all single patent families must have one filing authority. In order to isolate the effects from the number of inventor countries from the size effects, we control the size of families as measured by the number of patent applications.

We control time-fixed effects by including three dummies for priority year of family (for 2005, 2000, and 1995, referenced to 1990). Finally, technology effects are controlled by including 18 technology class dummies that we construct based on International Patent Class (referenced to “Basic chemicals, paints, soaps, petroleum products”).

The description of variables and sample statistics are presented in Table 1.

Table 1 Sample statistics and description of variables (N=860,222)

Variable	Description	Mean	Std. Dev.	Min	Max
nauth	Number of Filing authorities	3.004	2.751	1	51
dauth_EP	Filed in EPO	0.389	0.487	0	1
dauth_WO	Filed as PCT	0.340	0.474	0	1
big2all	Filed in EPO and as PCT	0.200	0.400	0	1
	Independent variables				
dcoinv	Dummy for international co-invention	0.071	0.257	0	1
iy95dcinv	dcoinv*d1995	0.010	0.101	0	1
iy00dcinv	dcoinv*d2000	0.023	0.149	0	1
iy05dcinv	dcoinv*d2005	0.032	0.176	0	1
	Controls				
famsaunr	Family size: number of applications	3.388	4.361	1	1020
d2005	Priority filing in 2005	0.377	0.485	0	1
d2000	Priority filing in 2000	0.291	0.454	0	1
d1995	Priority filing in 1995	0.187	0.390	0	1
dinvt_US	Inventor country - US	0.376	0.484	0	1
dinvt_JP	Inventor country - Japan	0.191	0.393	0	1
dinvt_DE	Inventor country - Germany	0.179	0.384	0	1
dinvt_GB	Inventor country - Great Britain	0.043	0.203	0	1
dinvt_FR	Inventor country - France	0.040	0.197	0	1
dinvt_CH	Inventor country - Switzerland	0.017	0.128	0	1
dinvt_CN	Inventor country - China	0.015	0.123	0	1
dinvt_KR	Inventor country - Korea	0.035	0.184	0	1
dapp_US	Applicant country - US	0.381	0.486	0	1
disi19_1	Electrical machinery, apparatus, energy	0.049	0.216	0	1
disi19_2	Electronic components	0.058	0.235	0	1
disi19_3	Telecommunications	0.086	0.280	0	1
disi19_4	Audio-visual electronics	0.025	0.156	0	1
disi19_5	Computers, office machinery	0.132	0.338	0	1
disi19_6	Measurement, control	0.060	0.237	0	1
disi19_7	Medical equipment	0.052	0.221	0	1
disi19_8	Optics	0.028	0.165	0	1
disi19_9	Basic chemicals, paints, soaps, petroleum products ***(reference category)***	0.050	0.218	0	1
disi19_10	Polymers, rubber, man-made fibres	0.054	0.226	0	1
disi19_11	Non-polymer materials	0.040	0.197	0	1
disi19_12	Pharmaceuticals	0.061	0.239	0	1
disi19_13	Energy machinery	0.033	0.179	0	1
disi19_14	General machinery	0.030	0.171	0	1
disi19_15	Machine-tools	0.020	0.139	0	1
disi19_16	Special machinery	0.055	0.228	0	1
disi19_17	Transport	0.070	0.256	0	1
disi19_18	Metal products	0.025	0.157	0	1
disi19_19	Textiles, furniture, food etc.	0.070	0.255	0	1

4. Trends in International Patent and Co-Patent Applications

4.1 Patents

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 only at the national level before is now more and more also applied 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 many countries follow an extreme upsurge of patent filings. After the year 2000 this development was discontinued caused by the economic downswing of this period, which especially affected the leading-edge[3] 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.

4.2 Co-patents

International co-patents have rapidly grown since the 1990s (see Frietsch and Jung 2009). In the case of filings to the EPO and to WIPO under the PCT procedure, the number of co- has almost quintupled since 1991 and doubled since mid-90s. The compound annual growth rate of total co-patents exceeds the annual growth rate of total world patents for the same period. Except for the Asian countries Japan, Korea, and China, the growth of co-patents exceeds the growth of total patents in many

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[3] 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).

industrialised countries. 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 in the recent years. 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. Switzerland and Canada have a strong presence of co-patents and show high growth rates. 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.

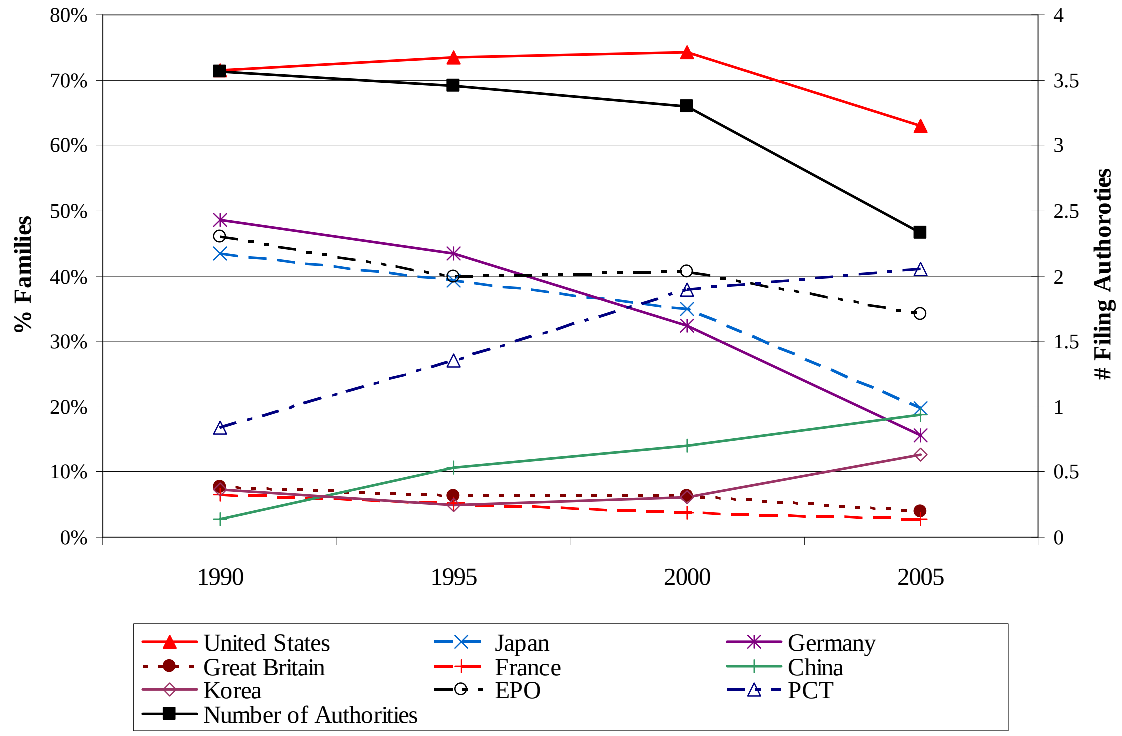
Recent OECD studies support these findings of increasing importance of international co-patents (OECD 2007; Guellec, Zuniga 2007). Guellec and Zuniga (2007) point to casual evidence which suggests that overall patent data tend to underestimate the degree of internationalisation of technology production and use. In general, co-patenting is increasing and obviously also of increasing importance. However, this is an opportunity for us to analyse the internationalisation of the markets that these international co-patents are targeting. To the best of our knowledge, this is not done so far – or at least not published so far.

5. Data Analysis

5.1 Sample characteristics

In the sample, patents are filed in 3 authorities, on average. Figure 1 shows the decreasing trend of the number of filing authorities between 1990 and 2005. This may be explained by increasing number of PCT filings. The most favored filing authority in the sample is the USPTO which accounts for around 70% of families. Germany was the second most favored office in 1990 in which almost 50% of families were filed. However, only about 16% of families choose to file in German national office in 2005. The decreasing trends of national filings are similarly observed for France and Great Britain. This is due to the increasing patenting activities of technologically emerging countries such as China and Korea and increasing adoptions of international filings.

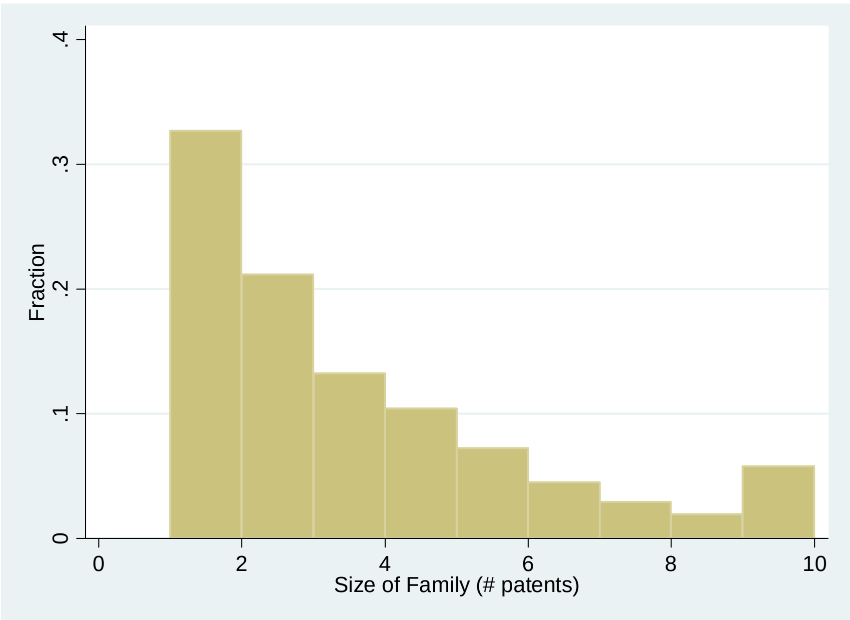
Figure 1: Trends of filing authorities of patent families



Source: PATSTAT (EPO Worldwide Patent Statistical Database); Fraunhofer ISI calculations.

In the sample, about one-third of families are single-patent families. One-fifth of the families have more than 5 patent applications (Figure 2). This indicates that traditional approach based on a single patent as the unit of analysis may mislead especially in international comparative studies.

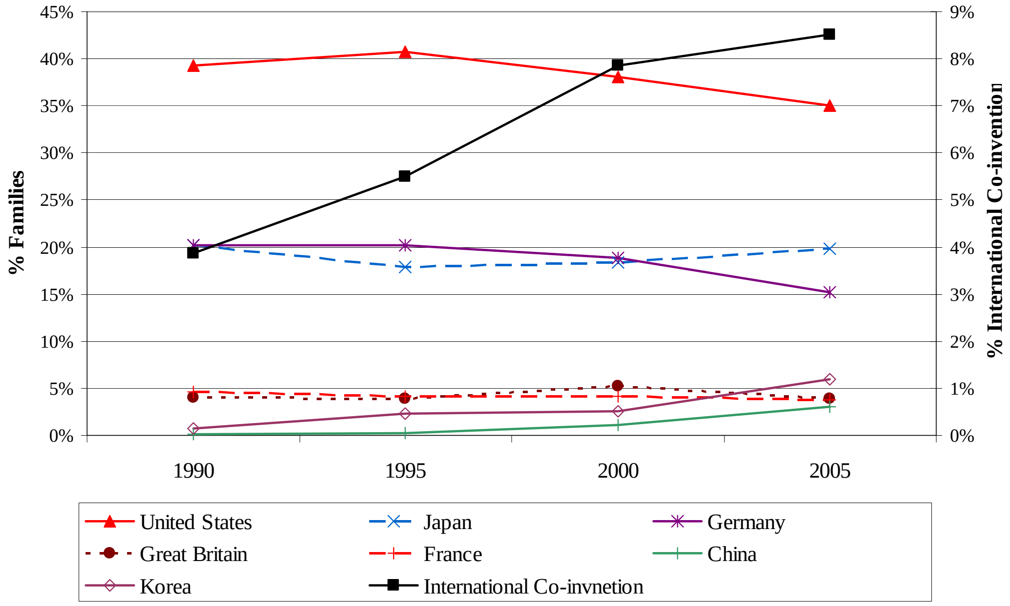
Figure 2 Distribution by the size of family



Source: PATSTAT (EPO Worldwide Patent Statistical Database); Fraunhofer ISI calculations.

Trends of inventor countries are shown in Figure 3. One notable trend is increase of international co-invention as defined by family of patented invented by persons residing in two or more countries at the time of invention. The proportion of international co-invention has doubled during the sample period - from about 4% in 1990 to 8.5% in 2005. In terms of inventor countries, while the traditional strongholds (such as United States, Japan, Germany, etc.) are either stable or slightly decreasing, technologically emerging countries such as China and Korea show a steep increase.

Figure 3 Trends of inventor countries and international co-invention



Source: PATSTAT (EPO Worldwide Patent Statistical Database); Fraunhofer ISI calculations.

5.2 Multivariate analysis

We first estimate the effects of international co-invention on international filings using count of different filing authorities as the dependent variable. Because the dependent variable is discrete integer between 1 and 51, we estimate the effects using the negative binomial regression models. Negative binomial model is preferred to Poisson model because there is significant evidence of over-dispersion (p<0.001; See lnalpha in Table 2). Next, we estimate the probability of filing in international authorities (EPO and PCT) using the logistic regression models.

Table 2 presents the results of estimation. Columns 1 and 2 are the estimation from the negative binomial models and the rest of columns are from logistic regressions with indicator variables for EPO and PCT filings and the union of them as dependent variables. The last column shows the estimation with interaction terms added. All models pretty well fit with the data and have high explanatory powers.

Because of very large N (=860,222), almost all covariates are significantly associated with the respective dependent variables. The size of family (famsaunr) is positively associated with international filings as expected. The decreasing trends of international filings are still maintained after controlling for a variety of factors as indicated by negative signs on the priority year dummies in column 1 and 2. However, this does not indicate that international filings are decreasing because the time effects on the propensity to choose PCT route are actually increasing. Therefore, we can conclude that the decrease of the breadth of national authorities may have been substituted by increasing choice of PCT filings.

Inventors from the United States, Germany and China are likely to file patents in smaller number of authorities. On the other hand, inventors from Japan, France, Switzerland and Korea are likely to file in large number of authorities. Turning to the effects of inventor countries on propensity to file in particular authorities, there is significant home country bias. European inventors (except British) are likely to favor EPO while non-European inventors are less likely to file in EPO. Our results indicate that British inventors are particularly more likely to take PCT route of filings (column 4).

Looking at the technology dummies, the coefficients of all technology dummies in column 1 and 2, referenced to basic chemical technologies, are significantly and negatively associated with the number of filing authorities. This indicates that basic chemical technology is highly internationalized field. Also, basic chemical technologies are most likely to file for PCT as indicated by negative signs of technology dummies of the PCT regression in column 4.

Turning to the key variable of interests, in column 1 and 2, internationally co-invented patents are likely to file in larger number of patent authorities as predicted by the hypothesis (as indicated by positive and significant coefficients on dcoinv). Also, internationally co-invented families are more likely to file in international offices such as EPO or PCT. Interestingly, the effects of international co-invention on international filings become stronger in the recent years. The coefficients on the interaction terms of co-invention with priority year 2005 and 2000 show significant and positive estimates.

Table 2 Estimation results (regression coefficients reported)

	Negative Binomial (DV=# authorities)		Logistic Regressions			
	Main model	Adding interaction	DV= dauth_EP	DV= dauth_WO	DV= big2all	DV= big2all, adding interaction
dcoinv	0.139***	0.028***	0.318***	0.391***	0.469***	-0.846***
	(0.003)	(0.010)	(0.014)	(0.011)	(0.013)	(0.099)
iy05dcinv		0.196***				1.383***
		(0.010)				(0.101)
iy00dcinv		0.099***				1.485***
		(0.011)				(0.102)
iy95dcinv		0.019				1.076***
		(0.012)				(0.108)
d2005	-0.114***	-0.127***	0.303***	2.073***	2.458***	2.379***
	(0.002)	(0.002)	(0.010)	(0.012)	(0.019)	(0.019)
d2000	-0.034***	-0.038***	-0.255***	1.557***	1.692***	1.602***
	(0.002)	(0.002)	(0.011)	(0.011)	(0.018)	(0.018)
d1995	-0.037***	-0.036***	-0.337***	0.869***	1.082***	1.025***
	(0.002)	(0.002)	(0.012)	(0.012)	(0.019)	(0.019)
famsaunr	0.125***	0.125***	1.019***	0.297***	0.512***	0.513***
	(0.001)	(0.001)	(0.004)	(0.002)	(0.003)	(0.003)
dinvt_US	-0.178***	-0.178***	-0.934***	-0.348***	-0.400***	-0.403***
	(0.002)	(0.002)	(0.009)	(0.007)	(0.009)	(0.009)
dinvt_JP	0.102***	0.102***	-1.017***	-0.875***	-1.025***	-1.027***
	(0.002)	(0.002)	(0.011)	(0.009)	(0.012)	(0.012)
dinvt_DE	-0.086***	-0.087***	0.217***	-0.736***	-0.278***	-0.282***
	(0.002)	(0.002)	(0.010)	(0.009)	(0.011)	(0.011)
dinvt_GB	0.018***	0.019***	-0.146***	0.150***	0.175***	0.174***
	(0.003)	(0.003)	(0.016)	(0.013)	(0.015)	(0.015)
dinvt_FR	0.170***	0.168***	0.952***	-0.213***	-0.126***	-0.133***
	(0.003)	(0.003)	(0.017)	(0.015)	(0.017)	(0.017)
dinvt_CH	0.052***	0.054***	1.063***	-0.362***	-0.199***	-0.186***
	(0.004)	(0.004)	(0.029)	(0.023)	(0.028)	(0.028)
dinvt_CN	-0.051***	-0.074***	-1.284***	-0.000	-0.862***	-0.892***
	(0.005)	(0.005)	(0.027)	(0.020)	(0.026)	(0.026)
dinvt_KR	0.144***	0.144***	-2.049***	-1.124***	-1.742***	-1.742***
	(0.003)	(0.003)	(0.020)	(0.016)	(0.024)	(0.024)
disi19_1	-0.130***	-0.130***	-0.350***	-0.796***	-0.527***	-0.530***
	(0.003)	(0.003)	(0.019)	(0.016)	(0.021)	(0.021)
disi19_2	-0.142***	-0.144***	-0.872***	-1.050***	-0.733***	-0.741***
	(0.003)	(0.003)	(0.020)	(0.016)	(0.021)	(0.021)
disi19_3	-0.115***	-0.116***	-0.083***	-0.485***	-0.187***	-0.193***
	(0.003)	(0.003)	(0.017)	(0.014)	(0.018)	(0.018)
disi19_4	-0.124***	-0.125***	-0.100***	-0.651***	-0.270***	-0.276***
	(0.004)	(0.004)	(0.022)	(0.020)	(0.025)	(0.025)
disi19_5	-0.176***	-0.177***	-0.456***	-1.027***	-0.712***	-0.718***
	(0.003)	(0.003)	(0.016)	(0.014)	(0.018)	(0.018)

disi19_6	-0.085***	-0.086***	-0.191***	-0.323***	-0.006	-0.011
	(0.003)	(0.003)	(0.018)	(0.015)	(0.019)	(0.019)
disi19_7	-0.079***	-0.080***	-0.039**	-0.064***	0.115***	0.111***
	(0.003)	(0.003)	(0.019)	(0.015)	(0.019)	(0.019)
disi19_8	-0.132***	-0.133***	-0.547***	-0.838***	-0.641***	-0.647***
	(0.004)	(0.004)	(0.023)	(0.019)	(0.026)	(0.026)
disi19_10	-0.040***	-0.041***	0.010	-0.358***	-0.202***	-0.205***
	(0.003)	(0.003)	(0.019)	(0.016)	(0.020)	(0.020)
disi19_11	-0.078***	-0.079***	-0.229***	-0.394***	-0.311***	-0.315***
	(0.003)	(0.003)	(0.021)	(0.017)	(0.022)	(0.022)
disi19_12	-0.047***	-0.048***	0.237***	1.006***	0.629***	0.626***
	(0.003)	(0.003)	(0.018)	(0.016)	(0.018)	(0.018)
disi19_13	-0.086***	-0.087***	-0.405***	-0.821***	-0.571***	-0.575***
	(0.003)	(0.003)	(0.022)	(0.018)	(0.024)	(0.024)
disi19_14	-0.081***	-0.081***	-0.175***	-0.577***	-0.380***	-0.382***
	(0.004)	(0.004)	(0.022)	(0.019)	(0.024)	(0.024)
disi19_15	-0.085***	-0.086***	-0.268***	-0.777***	-0.524***	-0.528***
	(0.004)	(0.004)	(0.026)	(0.022)	(0.029)	(0.029)
disi19_16	-0.085***	-0.086***	-0.378***	-0.808***	-0.675***	-0.680***
	(0.003)	(0.003)	(0.019)	(0.016)	(0.021)	(0.021)
disi19_17	-0.121***	-0.121***	-0.339***	-0.939***	-0.614***	-0.617***
	(0.003)	(0.003)	(0.018)	(0.015)	(0.019)	(0.019)
disi19_18	-0.182***	-0.182***	-0.225***	-1.022***	-0.801***	-0.804***
	(0.004)	(0.004)	(0.023)	(0.021)	(0.027)	(0.028)
disi19_19	-0.176***	-0.176***	-0.396***	-0.784***	-0.606***	-0.609***
	(0.003)	(0.003)	(0.018)	(0.015)	(0.020)	(0.020)
Constant	0.742***	0.746***	-2.741***	-2.151***	-4.357***	-4.283***
	(0.004)	(0.004)	(0.020)	(0.018)	(0.027)	(0.027)
lnalpha	-2.306***	-2.307***				
	(0.024)	(0.024)				
Observations	860222	860222	860222	860222	860222	860222
Log Likelihood	-1488760	-1488355	-327040	-445881	-297649	-297289
Pseudo-R-squared	0.181	0.181	0.431	0.192	0.309	0.310

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: PATSTAT (EPO Worldwide Patent Statistical Database); Fraunhofer ISI calculations.

6. Summarising Conclusions

The numbers and also the shares of internationally co-invented patents have considerably increased over time. Obviously the importance of cross-border collaborations and thus of cross-border knowledge flows has increased in the recent decade. We estimated the effects of international co-patents on the fact and the size of international targeted markets. This is still work in progress, but our first results indeed show a higher internationalisation of internationally co-invented patents. Internationally co-invented patents indeed are more often filed internationally compared to pure national inventions. Further analyses are necessary, especially as we found some indications of a change over time and also for a u-shaped impact. It seems that the number of inventors has a positive impact on the international filing activities, but with very high numbers of different inventor countries, the number of filing authorities is shrinking again. However, it also seems that first of all the inventor countries are also approached as target markets. This could be interpreted as a proof of complementary knowledge seeking, but further analyses are necessary to support this very preliminary result.

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