Micro evidence on international patenting

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Micro Evidence on International Patenting

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Abstract

Globalization, high growth rates in high-tech industries, growing emerging markets and harmonization of patent institutions across countries have stimulated patenting in foreign markets. We use a simple model of international patenting, where the decision to patent in a foreign country depends on country characteristics and the quality of the patented invention. With access to a detailed database on individual patents owned by small Swedish firms and inventors, we are able to estimate some of these relationships and test their validity. Our results indicate that the propensity to apply for international patent protection increases with indicators of the quality of the invention, technological rivalry and market size in the host market.

JEL classification: O33, O34

Keywords: International patenting, host country characteristics, patent value indicators

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1. Introduction

It is now widely accepted that the processes through which new technology is invented, commercialized and spread to many users across the global economy are important for economic growth, catch-up and development.

Patenting plays a key role for technology diffusion. On the one hand, intellectual property rights (IPRs) limit technology diffusion since imitation becomes illegal and costs for acquiring new technology increases through owners' monopoly positions. At the same time, IPRs may increase incentives for innovation and therefore flows of new technology. Furthermore, patenting requires that the applicant reveals basic information about the invention, which becomes public. The academic and (heated) political debates on the TRIPS (Trade related aspects of intellectual property rights) agreement in the World Trade Organization (WTO) reflect these tensions.[1]

Our framework takes the IPR institutions as given and focuses on their functioning as a conduit. A patent in a specific country protects the inventor, both from imitators producing in that country and from outside imitators selling there. To get a wider geographical protection, the inventor has to apply for patent equivalents, i.e. parallel patents for the invention in several countries. Accordingly, patent protection increases with the number of patent equivalents, i.e. with the size of the patent family. But to apply for patents in many countries is costly. Therefore, the decision to apply for patent protection in a given country reflects a tradeoff between gains and costs. With this approach, international patenting signals that the IPR owners expect their technology to have a market abroad and therefore diffusion of the patented technology to these markets.

Recent decades have seen a trend towards strengthening and harmonization of patent institutions across nations and regions. At the same time, international patenting has been increasing in importance. In 2010, more than 40 percent of all patent applications in the world's patent offices were from non-residents (WIPO 2011). But still, most patents are patented in only one or just a few countries.

The purpose of this study is to analyze the international patenting strategy of small firms and inventors. A theoretical model derived from Eaton and Kortum (1996) is set up to analyze the patentees' choice to patent in foreign countries. The model predicts that the probability of patenting in another country is related to characteristics of the invention and indicators of the market where patent protection is applied for, like market size, growth rate and patenting costs. In the empirical analysis, we use a detailed database on patents owned by small Swedish firms and inventors. The database contains information on patent equivalents, several patent value indicators and characteristics of the firms and the inventors. This database is complemented with host country characteristics. The database is therefore appropriate for microeconometric analysis. We find that the results in the empirical estimations are in accordance with the model's predictions. Whereas most earlier studies have used aggregated patent data to infer about international patenting, in this study we make use of micro level data at the patent and at the country level. This is the main contribution of the study.

Our topic is important. First, as noted, international patenting provides one (of several) channel for international technology diffusion. By investigating determinants of international patenting, determinants of technology diffusion may also be revealed. Second, with international heterogeneity in IPR institutions, their impacts can be evaluated.

The paper is organized as follows. Some trends in international patenting are discussed in section 2. In section 3, the database and some statistical tests are presented. In section 4, we set up a theoretical model for international patenting. Econometric methodology and hypotheses for explanatory variables are discussed in section 5. Section 6 presents our empirical results and the final section draws several conclusions.

2. International patenting

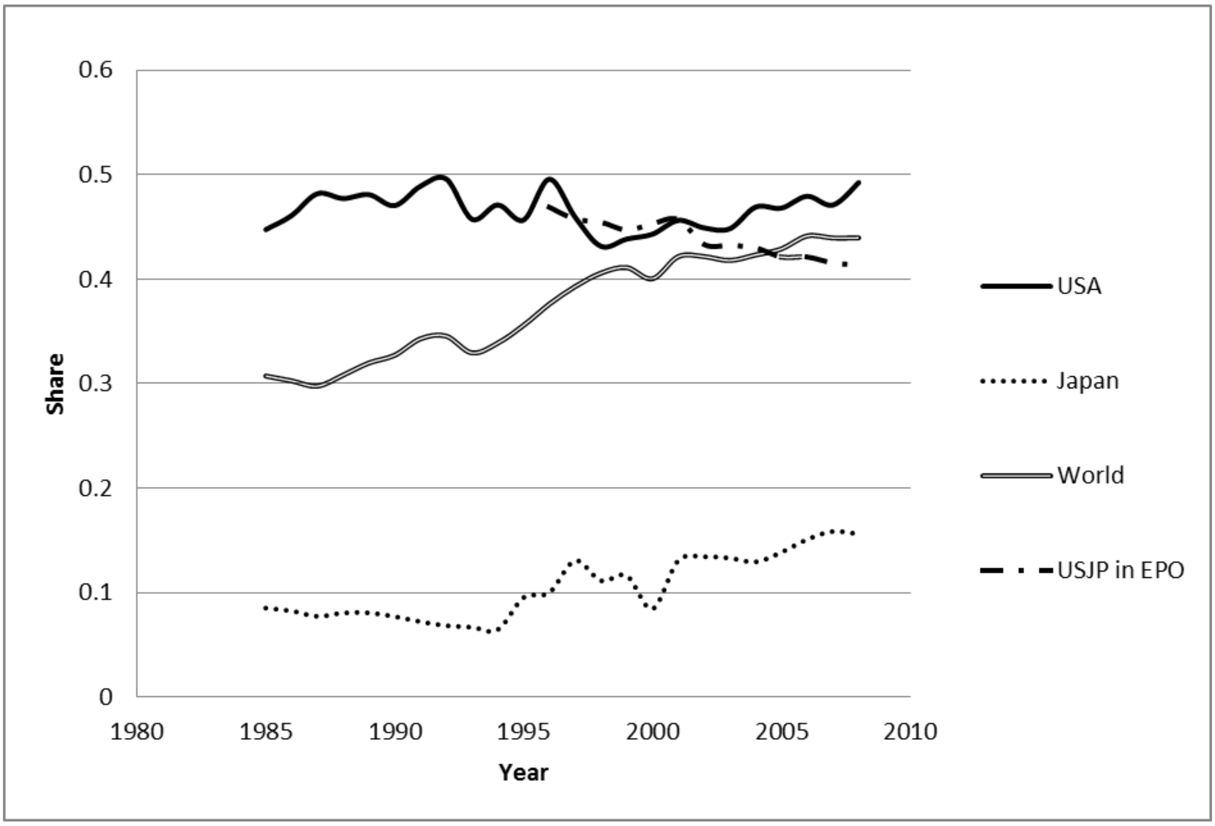
IPR protection has traditionally been the domain of nation states. But international treaties ─ from the Paris convention in 1883 to the TRIPS in 1995 and subsequent agreements ─ have dictated convergence in IPR institutions. International patentees are guaranteed national treatment by increasingly similar IPR institutions across the world.[2] Thus, international patenting is facilitated by institutional reforms.

Patents in specific countries can be filed directly with national patent offices. For example, in Sweden patents are filed with the Swedish Patent and Registration Office

(PRV). Once a patent is filed with any patent office, the inventor must within a year file patents with other offices if he wished to expand the patent right to other countries (the priority year). In Europe, a European patent can be filed with the European Patent Office (EPO). The invention will then be protected in as many members of EPO (40 countries) as desired. If patents are desired in many countries worldwide, the inventor can make an international PCT-application either with the national patent office, EPO or the World Intellectual Property Organization (WIPO).[3] This can lead to a patent covering a total 148 countries (as of 2013).

Comparing the three large patenting areas (called the Triad), the EPO-system is much more fragmented than the U.S. and Japanese systems (van Pottelsberghe 2009, 2010; van Pottelsberghe and Francois 2009). The costs for EPO-patents are considerably higher, since patents have to be validated and subsequently renewed in each member state where patent protection is sought.[4] Furthermore, there is no unitary European litigation court.

Figure 1. Share of non-resident patents

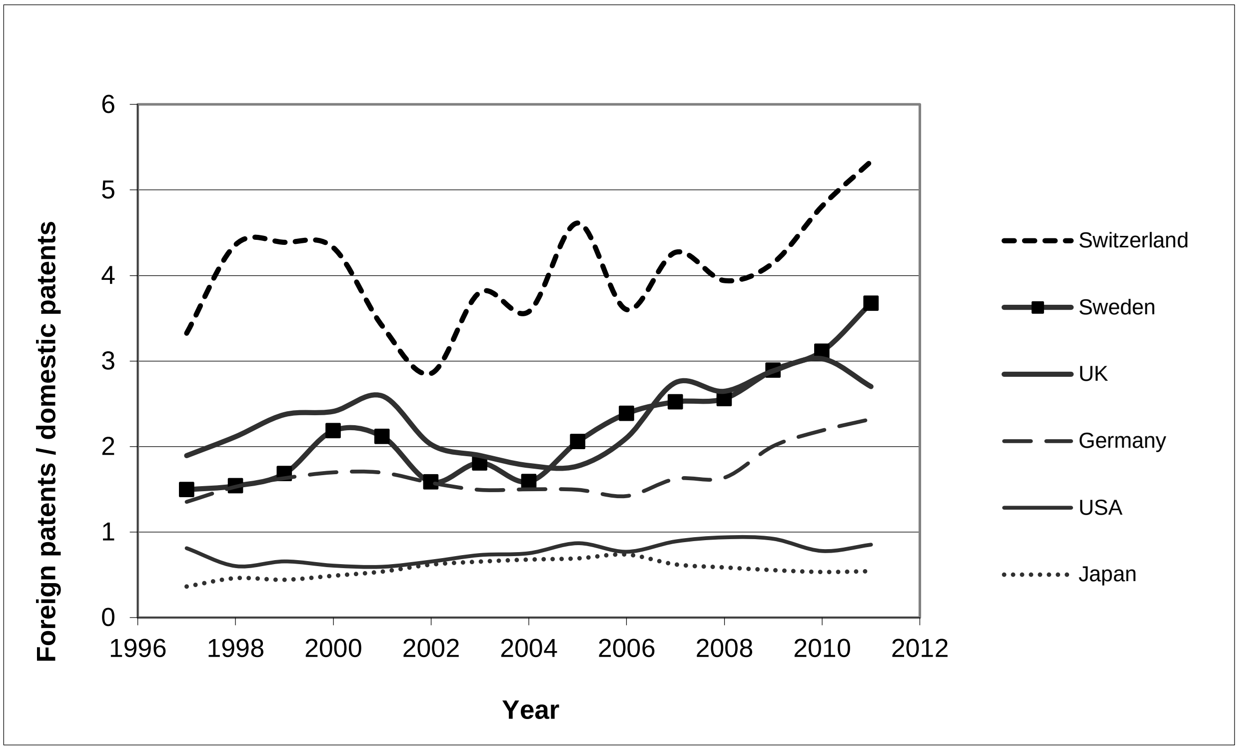


Source: WIPO (2011).

International patenting has increased in importance in recent years. For the world economy, the number of patent families ─ i.e. the number of patented inventions, including their international patent equivalents ─ has increased by around 80 percent from 1990 to 2006 (WIPO 2011).

Figure 1 shows developments of the share of non-resident patent applications for all countries, and for the U.S. and Japan. For EPO, the figure graphs the U.S and Japanese share of patent applications (since the number of countries who are members of EPO has changed over time). Figure 1 indicates that non-residents slowly have increased their share of patenting in major economies (except for U.S. and Japanese patentees in the EPO). Since the number of patent families has increased, the increasing shares of non-resident patent applications clearly suggest international patenting has grown in importance.

Figure 2 Shares of foreign patents relative to domestic patents by country of origin of patentees



Source: WIPO (2013)

While Figure 1 shows share of non-resident patents, Figure 2 illustrates foreign patents from 1997 to 2011 as a ratio of domestic patents by the country of origin of patentees. Since a domestic patent may have several patent equivalents abroad, this ratio can be higher than 1. Foreign patents outnumber domestic patents, especially for countries with limited domestic markets. The graph indicates that foreign patenting has become more attractive for patent owners in most countries in the figure except from Japan and the U.S.[5]

The trends above indicate that international patenting is of great importance and it has received increasing attention in the research literature. Penrose (1951) is an early overview of the international patent system. Slama (1981) pioneers analyses of international patenting with the use of the traditional gravity model, finding that market size (positively) and distance (negatively) influence bilateral international patent patterns. Evenson (1984) discusses trends in international patenting, showing there are comparative advantage patterns in innovation similar to the patterns observed in countries' production. Thus, industrial knowledge production is concentrated in countries according to their comparative advantages and international patenting reflects international trade patterns. Harhoff *et al*. (2009) use a gravity model framework to evaluate patent policies and to explore determinants of international patenting. We use a similar approach, albeit with a microeconomic structure, to investigate patent holders' decisions to patent internationally. Chan (2010) uses a limited dataset on nine agricultural biotechnology firms to analyze the probability of international patent applications in seven countries. Chan's results indicate that invention quality plays an important role in firms' decision to patent abroad in addition to business climate and patent enforcement across countries.

Eaton and Kortum (1996 and 1999) and McCalman (2005) use international patenting and international copyrights to make inferences about international technology diffusion (McCalman for the case of Hollywood movies). Eaton and Kortum (1996) hypothesize that technology diffusion contributes to economic growth and that international patenting indicates such diffusion. They model and estimate a general equilibrium growth model for many countries, based on innovation and diffusion. Eaton and Kortum (1999) construct a related model where R&D efforts are endogenized. McCalman (2001) also uses the Eaton and Kortum framework to investigate the distribution of rents from patenting between countries as a function of IPR institutional design. More recently, Branstetter *et al.* (2006) investigate technology transfers within U.S. multinationals as a function of changes in other countries' IPR regimes.

From another perspective, international patenting has been used as an indicator of the value of the patented invention. Putnam (1996) and Lanjouw, Pakes and Putnam (1996) are pioneering contributions. Several studies have found that the size of the patent family is positively related to patent or firm value (Schmoch *et al.* 1988; Lanjouw and Schankerman 2001; Harhoff, Scherer and Vopel 2002). Only those inventions with sufficiently high value will be patented abroad, given the high costs in many countries to file and renew the patents. Lanjouw and Schankerman (2004) construct an index of patent quality based on multiple indicators of which the size of the patent family is one. Below we analyze international patenting as a function of other patent quality indicators.[6]

Our hypothesis is that inventions with high values tend to be patented more often internationally than inventions with low values. We therefore relate international patenting to indicators of patent quality. We rely on two main indicators. These are patent renewal data and patent citations data. Patent renewal data has been used extensively as an indicator of the private value of patent protection. In most countries patents have to be renewed periodically, and a renewal fee has to be paid, in order to keep the patent in force. If the value of patent protection deteriorates and when patent renewal fees increase over time, more valuable patents are renewed for longer periods than less valuable patents. Pakes and Schankerman (1984), Schankerman and Pakes (1986), Pakes (1986), Pakes and Simpson (1989) and Schankerman (1998) are main contributions in this research tradition. They all estimate patent value distributions on the basis of this hypothesis. We use a simple patent renewal indicator as a value indicator for patents and relate it to international patenting.

Also citations to previous patents in patent documents are used as indicator of the quality of the patented invention. Backward citations (*i.e.* cited patents in patent documents) have been used to track the knowledge base for the patented invention. Forward citations are therefore used as indicator for whether the patented invention has opened windows of opportunities in subsequent research. Important contributions in this research tradition are collected in Jaffe and Trajtenberg (2002). A main conclusion is that forward citations signal higher private value of patents. This is also the conclusion in Hall *et al.* (2005) who find that patent citations are positively correlated with firms' market values. Harhoff *et al.* (1999) find similar evidence based on a survey about the value of a sample of patents.[7] Serrano (2010) find evidence that frequently cited patents are more likely to be traded commercially (and renewed).

We also use a dichotomous indicator for whether the patented invention has been commercialized. This reflects a potential direct quality indicator of the patent since it has proved worth market launch.[8]

The growing literature on patent value indicators has been surveyed by van Zeebroeck (2011) and van Zeebroeck and van Pottelsberghe (2011).

3. Database and descriptive statistics

We use a detailed data set on patents granted to small firms (less than 1000 employees) and individual inventors. The data set is based on a survey conducted in 2003−04 on Swedish patents granted in 1998. In that year, 1,082 patents were granted to Swedish small firms and individuals.[9] Information about the inventors, applying firms and their addresses as well as filing dates for each patent, was collected from the Swedish Patent and Registration Office (PRV). Thereafter, a questionnaire was sent out to the inventors of the patents. 867 (out of 1,082) inventors completed and returned the questionnaire, i.e. the response rate was 80 percent. This attrition is not systematic with respect to IPC-classes or geographical regions.[10]

The questionnaire asked the inventors about the type of work place where the invention was created, if-when-and-how the invention had been commercialized, the profitability of the commercialization and miscellaneous information about characteristics of the inventors. The data set was later complemented with data on patent renewal, patent equivalents, forward citations and filing routes from the Espacenet (2010) website. Thus, the database includes information on several patent value indicators.

Table 1. Distribution of the number of patent equivalents in the database.

	Number of patent equivalents													
	0	1	2	3	4	5	6	7	8	9	10	11-15	16-20	21-24	Total
Number of observations (patents)	533	80	43	36	27	27	23	20	14	13	8	31	10	2	867

The 867 patents in the database have together 1,733 patent equivalents abroad, i.e. on average around two equivalents per patent. The frequency distribution of patent equivalents is shown in Table 1. Only 334 (39 percent) out of the 867 patents have any equivalents. Given that a Swedish patent has any equivalents, the average number of equivalents per patent is 5.2. The maximum number of equivalents for a given patent is 24.

There are in total patent equivalents in 35 different countries in the data set. The frequency for each country is shown in Appendix A, Table A1. There were 224 equivalents in the U.S. and 141 in Japan, as well as 217 EPO-patents. EPO-patents must be validated in individual member countries. The EPO-patents resulted in 1,104 individual patents in the EPO member countries, i.e. on average 5.1 individual patents per EPO-patent.[11] Only 30 equivalents were filed directly at the national patent offices in the EPO area without filing an EPO-patent first. The EPO-patents in our database are filed most frequently in Germany, Great Britain and France – the large EPO countries. Thus, patent equivalents are not distributed randomly across the countries.[12] Van Zeebroeck and van Pottelsberghe (2011) have shown that there is a strong positive correlation between market size and the probability that an EPO-patent will be validated in a country. The skewed country distribution of patents above indicates that country characteristics are important for international patenting.

Turning to the filing routes, only eight out of 867 patents were first filed abroad – all of these in the U.S. No patent was first filed with EPO or WIPO and thereafter in Sweden. This pattern contrasts markedly to the filing routes of Swedish multinationals. The explanation may be polygenetic, ranging from the fact that the owners in our database are individuals and small firms to the fact that the data cover patent filings in the 1990s when it was still common to first file the patent in the home country. However, it is noteworthy that PCT-applications are very frequent in the database. 269 out of 334 patents (80 percent) with foreign equivalents used PCT-applications. PCT-applications are even more dominant for EPO-patents (194 out of 217, or 89 percent) and for US patents (188 out of 224 patents, or 84 percent).

Table 2 shows partial relationships between the number of patent equivalents and firm sizes, patent renewal, forward citations and the commercialization decision. Firms have considerably more patent equivalents than individual inventors. For example, 57 percent of the medium sized firms had at least one equivalent, compared to 28 percent of the individual inventors. The differences in patent equivalents across firm groups are significant, using a chi-square test. However, there is no uniform relationship between firm size and equivalents. Micro companies have as many equivalents as small firms.

Table 2. Patent equivalents across firm groups, patent renewals, forward citations and commercialization, No. of patents and percent.

Categories		Patent equivalents abroad: Yes	Patent equivalents abroad: No	No. of patents per category	Average No. of equivalents	Chi-square test
Medium-sized firms (101–1 000 employees)		66 (57%)	50 (43%)	116	2.54	40.6 ***
Small firms (11–100 employees)		87 (43%)	114 (57%)	201	2.10	
Micro companies (2–10 employees)		66 (46%)	76 (54%)	142	2.44	
Individual inventors (no employees)		115 (28%)	293 (72%)	408	1.64	
Alive in 2004	Yes	247 (51%)	235 (49%)	482	3.09	74.2 ***
	No	87 (23%)	298 (77%)	385	0.63	
Forward citations	Yes	256 (73%)	94 (27%)	350	4.00	327.5 ***
	No	63 (12%)	454 (88%)	517	0.64	
Commercialization	Yes	251 (48%)	275 (52%)	526	2.62	47.7 ***
	No	83 (24%)	258 (76%)	341	1.04	
Total number of patents		334 (39%)	533 (61%)	867	2.00	

Note: ***, ** and * indicate significance at the 1%-, 5%- and 10%-level, respectively.

In line with the literature cited above, we expect that valuable inventions will be more frequently patented abroad than less valuable ones, since patenting is costly. Therefore, we expect international patenting to correlate with variables such as patent renewal, forward citations and commercialization, all of which are related to the private or social value of patents (see section 2).

As discussed in section 2, the literature on patent renewal hypothesizes that renewal signals commercial value of a patent..[13] Patents which had equivalents were considerably more likely to still be renewed in 2004 (alive) than those without: 51 percent of the patents that were still valid in 2004 had equivalents, but only 23 percent of the expired patents.

The positive relationship is even stronger between patent equivalents and forward citations. Patents with citations had on average 4.0 equivalents, compared to 0.64 for patents without citations. 73 percent of the cited patents had equivalents, compared to only 12 percent for the non-cited. Forward citations are used as a measure on the social value of patents. One explanation for this is that patents that are cited by subsequent patents may be considered to be basic inventions which are useful for subsequent development of new knowledge. However, there may also be other reasons why this correlation is so high. Citations are most often added by independent patent examiners in the patent offices. When a Swedish patent has equivalents abroad it may be much more visible for patent examiners. This will increase the probability that the patent is cited, even if the citations do not signal higher values for the cited patent.

Finally, commercialized patents have more frequent patent equivalents than non-commercialized ones. The commercialization decision should reflect a higher private value. 48 percent of the commercialized patents have equivalents, compared to 23 percent of the non-commercialized ones. The chi-square tests categorically reject independence between commercialization and equivalents.

4. A model set-up for international patenting

We use a simple model of international patenting, where the decision to patent in a foreign country depends on country characteristics and the quality of the patented innovation. Our model is a simplified and modified version of Eaton and Kortum (1996). Their model is a fully fledged international general equilibrium growth model in which international patenting plays an important role. In Eaton and Kortum’s model, R&D improves on the quality of input factors used in production processes domestically and in other countries. The degree to which an invention is used in other countries’ production processes depends on the probabilistic size of each invention. If the invention is used in a country’s production process, the owner of the invention sells the technology monopolistically to the producer in that country. The owner of the invention faces a risk of imitation, which depends on whether or not the invention is patented. Eaton and Kortum (1996) develop the steady state growth paths in the model. This steady state is characterized by similar growth rates in all countries, but lower productivity in countries with low investments in R&D and little use of other countries' technologies. The incentives to do R&D and patent internationally depend on market size, protection of IPRs and a set of other parameters.

Given the scope of this paper, our set-up is less ambitious and meant to provide a rough microeconomic theory basis for our empirical specification of international patenting. Our available data are micro data that allows us to focus on and formulate patent owners' choice about where to patent.

The model is a quality ladder model of innovation à la Grossman and Helpman (1991a). Output in each country is produced with the help of intermediates, according to a constant returns to scale Cobb-Douglas production function:

1) $$\ln Y = \int_0^1 \ln\left(Z_v X_v\right) d_v$$

where Y denotes production, X_v the quantity of intermediate v and Z_v its quality.

Improvements in the quality of intermediates are the result of R&D and inventions. An invention improves on the quality of an intermediate such that the new generation of the intermediate Z'_v relates to the previous generation, Z_v according to:

$$Z'_v = e^q Z_v$$

The size or quality of the invention, q, is random so that the patenting decision is heterogeneous. Inventions that are large will be patented widely; whereas small inventions will only be patented in the home country of the owner.

Intermediates are produced under a simple production technology where one hour work is needed to produce one unit. The final good is a numeraire, so given a wage level, w, the price charged by a firm producing the intermediate with the highest available quality, e^q, is given by equation 2. This equation implies *limit pricing* where the leading firm in the market marginally undercuts the optimal price charged by the firm with the next highest quality (Bertrand pricing). The incumbent firm's price equals w after the leader has entered the market. The produced quantity for a firm producing the intermediate *v* depends on the demand function derived from equation 1. This demand function is given by equation 3.

2) $$p_v = e^{q_v} w$$

3) $$X_v = \frac{Y}{p_v} = \frac{Y}{e^{q_v} w}$$

Profits from an invention of size *q* are therefore equal to:

4) $$\pi_v = p_v X_v - wX_v = \frac{e^{q_v} wY}{e^{q_v} w} - w\frac{Y}{e^{q_v} w} = \left(1 - e^{-q_v}\right)Y$$

Equation 4 relates profitability of innovations to market size. This proves to be an important empirical regularity.[14]

A patent reduces the probability that the invention will be imitated in any period during the lifetime of the patent, from *k* to zero. For simplicity we assume that patents last forever,[15] and we also assume that if a patent is imitated, the profits for the inventor are reduced to zero. The discounted values of an unpatented and patented invention of quality *q* in country *j* are therefore:

5) $$V(q)_j^{nopatent} = \int_0^\infty \left(1 - e^{-q}\right) Y_j e^{g_j s} e^{-(r+k)s} ds$$

6) $$V(q)_j^{patent} = \int_0^\infty \left(1 - e^{-q}\right) Y_j e^{g_j s} e^{-rs} ds$$

Above, *r* denotes the discount rate and *g* the growth rate in the economy. The value of patenting is the difference $V(q)_j^{patent}$-$V(q)_j^{nopatent}$. The inventor will seek patent protection if this difference exceeds the cost of patenting in country *j*, C_j. Therefore the equality

7) $$V(q^*)_j^{patent} - V(q^*)_j^{nopatent} = C_j$$

determines the threshold quality level *q** such that innovations of higher quality are patented and those with lower qualities are not. Therefore the threshold value q_j* for a patent to be patented in country *j* is given in equation 8. The derivation of it is presented in Appendix C.

8) $$q_j^* = -\ln\left(1 - \frac{C_j\left(r - g_j\right)\left(r + k - g_j\right)}{Y_j k}\right)$$

It is evident from equation 8 that the threshold value q_j depends on patent costs, market size, interest rate, the growth rate and the risk of being imitated without patenting. The higher the threshold value the lower is the probability that an invention is patented in the particular market.

Let the size of an invention depend on a vector of patent specific characteristics, $\boldsymbol{\lambda}_\mathbf{i}$, and the realization of a random variable Q drawn from a probability distribution, so that $P(Q<q) = F(q)$.[16] We formulate the size of an invention i as the product of realizations of Q and patent specific characteristics captured by the vector $\boldsymbol{\lambda}_\mathbf{i}$ with coefficient vector $\boldsymbol{\beta}$, $q_{ij} = q\boldsymbol{\lambda}_i\boldsymbol{\beta}$. For patenting to occur it must be that, $q_{ij}>0$, which imposes parameter restrictions for the vector $\lambda_i\boldsymbol{\beta}$. The threshold realization of Q for a patent i to be patented in country j is:

9) $$q_{ij}* = -\left(\frac{1}{\boldsymbol{\lambda}_\mathbf{i}\boldsymbol{\beta}}\right)\ln\left(1-\frac{C_j(r-g)(r+k-g)}{Y_j k}\right)$$

The following results are easily derived:

Lemma

$$sign\left(\frac{dq_{ij}*}{d\lambda_i}\right) = -sign(\beta)$$

$$\frac{dq_{ij}*}{dC_j} > 0$$

$$\frac{dq_{ij}*}{dY_j} < 0$$

$$\frac{dq_{ij}*}{dg_j} < 0$$

$$\frac{dq_{ij}*}{dk_j} < 0$$

The first of these results means that the impact of patent characteristics on the threshold realization of Q for patenting is the negative of the parameter β (to be estimated). Thus patent characteristics that increase the value of a patent lower the threshold value realization of Q for patenting. Patent characteristics that reduce patent value increase the threshold. Accordingly, the higher the quality of the patent, the higher is the probability that the invention is patented in any country. The second results imply that the higher the patenting costs, the higher the threshold value for the quality of an invention to be patented. Therefore, the higher the patenting costs in a country, the lower the probability that an invention will be patented in that country. The third result means that the larger the GDP of a country the lower the threshold value for the quality of an invention to be patented. Therefore, the probability that an invention will be patented will be increasing with the market size of a given country. The fourth and fifth results are similar for growth in total GDP and risk of imitation in the absence of patenting.

Generally, the quality of patented inventions has unknown distributions. The exact functional form of the probability to patent is therefore not known. We approximate the binary choice (to patent or not) as:

$$10) \qquad PQ_{ij} = \begin{cases} 1 & \text{if } q_{ij} \geq q_{ij}^{*} \\ 0 & \text{otherwise} \end{cases}$$

Above, PQ_{ij} denotes whether a patent of quality q is patented in country j or not. The probability that the owner of a patent i seeks protection in a country j can be written as:

$$11) \qquad P\left(PQ_{ij} = 1\right) = f\left(\mathbf{T}_j \alpha + \boldsymbol{\lambda}_i \beta\right)$$

In equation 11, $\boldsymbol{T}$ denotes a vector of characteristics of the country in which patent protection is applied for, while $\boldsymbol{\lambda}$ denotes the vector of characteristics of the patented invention.

5. Econometric method and explanatory variables

Database

Our empirical strategy is to estimate variants of the above model. We use the patent dataset described in section 3. The uniqueness of our dataset is that it includes several individual patent value indicators, host country variables as well as patent-country variables corresponding to the explanatory factors in the theoretical model. This makes the dataset appropriate to estimate the implied relationships and test the hypotheses of the theoretical model. In our dataset, we have information on whether a patent has been granted in any of 35 countries (see Appendix A, Table A1). On the basis of this information, we create an expanded dataset consisting of 867*34 = 29,478 observations.[17] The unit of observation in this dataset is therefore the existence of a patent equivalent for patent *i* in country *j*.

Methodology

The dependent binary variable is whether the owner has patent protection for patent *i* in country *j*. International patent protection comes in addition to domestic (Swedish) patent protection, since the data base is constructed on the basis of the 1998 cohort of granted Swedish patents. Accordingly, we will use a model with a binary dependent variable to estimate how various explanatory variables are related to the patent protection in individual countries. The choice is the probit model.

Our dataset is two dimensional, along the patent dimension (i.e. different patents are protected in a given country) and the country dimension (one patent can be protected in different countries). The dataset therefore has panel data characteristics, although not in the standard cross observation over time dimensions. We therefore rely on a random effects probit model as our main empirical model, since a fixed effects model faces the incidental parameter problem, see e.g. Heckman (1981). In our set-up, the unobserved heterogeneity is on the patent-country level. This is formulated by assuming that the error term consists of two elements, $e_{ij} = \varepsilon_i + u_{ij}$, where ε_i captures elements that are country invariant and patent specific. The remaining noise is captured by u_{ij}.

Variables derived from the model

For the host country, *GDP* (in 1995) reflects market size and *GROWTH* captures GDP growth (in the period from 1990 to 2000).[18] The expected influence on the probability for a patent equivalent is positive and follows directly from our theoretical model (*Y* and *g*). *GDP* and *GROWTH* are collected from the World Development Indicators (World Bank 2011).

We have some proxies linked to the risk of imitation (*k*) in the model. All of these have an expected positive effect on patent equivalents:

- *RDGDP*. R&D as percent of GDP in the host country should reflect an increased probability of being imitated (from World Development Indicators).[19]
- *GDPCAP*. GDP per capita (in 1995) may reflect the technological level of the host country and a higher probability of being imitated (from World Development Indicators).[20]

- *NRCA*. We constructed a normalized version of the well-known revealed technological advantage (*NRCA*), which varies between −1 and 1 for each country for each patent class. *NRCA* is therefore expected to indicate potential competition and imitation of the patent in question. *NRCA* is patent (class) and country specific. We gathered the data from the NBER patent data base (Hall, Jaffe and Trajtenberg 2002; NBER 2006). The formula is given in Appendix D.

In line with the theory, we include total patent costs in the host country, *COST*. However, there is no patent cost index for all countries, inasmuch as the costs of patenting depend on several components, e.g. the filing costs. Very often (official) translation of the patent documents is required. If so, this adds a new cost component. Patentees are known to routinely use patent agencies for handling national patent offices which adds costs that can vary. Furthermore, annual renewal costs are added if the patent is granted. In most countries such renewal costs are low but increase as the patent matures. In Europe, patent protection can be applied in many countries via EPO. If so, the patent still needs to be validated and subsequently renewed in each of member countries individually. But patents in Europe can also be obtained through patent applications to each of the individual countries directly. We have chosen to use the patent costs from the survey by Helfgott (1993), even though Helfgott's cost data unfortunately covers only 20 of our 34 countries (see Table A1).[21] We report separate estimation results when *COST* is included.

Patent institutions vary in quality. Some countries provide strong IPRs while others are slack. We use the index described in Ginarte and Park (1997) and updated in Park (2008). This index is an average of indicators for patent coverage, membership in international treaties, duration of protection, enforcement mechanisms and restrictions. The database consists of observations for several years. We include countries' score in 1995 (*PARK95*). The index is designed to measure the strength of patent protection, not the (social) quality of patent systems.[22] We also include a dummy variable for EPO-membership.

Patent value indicators

The patent value indicators are taken from the database. The expected positive relationship to equivalents was discussed in section 3. Higher private value implies a higher probability of patenting the invention in any market.

- *ALIVE* is a dummy variable for whether the Swedish patent was still valid in 2004.
- *COM* is a dummy variable for whether the invention was commercialized.
- *CIT* measures the number of forward citations per five-year period. Since citation practices differ across IPC-classes, *CIT* is weighted by the number of citations per IPC-class.

Hall, Jaffe and Trajtenberg (2002) argue that patents that are cited across many technology fields are general and may have particularly wide applications for further technological developments. Maurseth (2005) argues that citations within technology classes signal competition and rival inventions to the cited patent, while citations across technology classes signal the higher private and social value of the patented invention. Therefore, we discriminate between intra-technology and inter-technology patent citations with the two variables *CITwi* and *CITbe* in most estimations.

We have reasons to believe that our data is characterized by endogeneity problems. If a patent proves valuable, it will probably have both a higher probability of commercialization, be renewed for longer periods, receive more forward citations *and* have a higher probability of being granted patent equivalents (see e.g. Svensson 2012). It is extremely difficult to tell in which direction causality runs between our right-hand value indicators and patent equivalents. Therefore, we include the patent value indicators successively in separate estimations and interpret the results with caution.

Other variables

Due to credit constraints, larger firms should have a higher propensity to apply for patent equivalents (see Table 2). Firm sizes are included in the estimations as dummy variables: *MED*, *SMALL* and *MICRO*. The reference group is inventors with no employees.

Distance between Sweden and the host country, *DIST*, should be included for two reasons. First, trade is known to depend negatively on distance. Therefore the value of patenting will be lower in distant countries (fewer goods are exported there). But it may also be the case that distance indicates higher (non-formal) costs of patenting in the country. The inventor may have to travel there. Also languages and cultures may well be more different and strange across long distances.

EXPSH is measured as Sweden's export share with the country in question.[23] We expect a high Swedish export share to identify an important market for Swedish producers, and thus higher propensities to patent in these countries.

Since patenting is known to vary much between industries and technology classes (Levin et al. 1987), we use additive dummies for 30 different industry classes designated by Breschi, Lissoni and Malerba (2004). These are based on the IPC technology class system. A patent may belong to several different IPC-classes. However, it is not possible to determine the main IPC-class, since the classes are listed in alphabetic order for each patent in Espacenet (2010). Therefore, a patent in our database may belong to as many as four different industry classes. Consequently, the 30 industry dummies are not mutually exclusive.

YEAR represents the application year of the Swedish patent. The data at hand is for the cohort of patents granted in 1998. Later application dates therefore indicate a relatively shorter time for consideration at the patent office. One interpretation is that patents under consideration for longer periods are more minor and dubious than patents granted after a short period. If this is the case, patents that were applied for early would have lower private values. Another interpretation is that long consideration reflects the complexity of the invention. [24]

All explanatory variables, basic statistics and their expected impact on patent equivalents are described in Appendix A, Table A2.

6. Results

Tables 3 through 5 present the empirical results estimated by the random effects probit model. The dependent binary variable is whether the owner has patent protection for patent *i* in country *j*.[25] The *COST* variable is excluded in Tables 3 and 4 due to data constraints, but is included in Table 5.

The parameter ρ (in the end of each table) is the proportion of the total variance contributed by the panel-level variance component in the dataset. If ρ is zero, the panel-level variance component is unimportant, and the panel level estimator is not different from the pooled estimator (StataCorp 2007). The estimated values of ρ are between ⅔ and ¾ and highly significant. This underlines the importance of taking due care of the panel data characteristics in the dataset.

Table 3. Results of estimations, random effects probit model.

Variable	*1*	*2*	*3*	*4*	*5*	*6*
GDP	0.67***	0.67***	0.67***	0.67***	0.67***	0.67***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
GROWTH	0.13***	0.13***	0.13***	0.13***	0.13***	013.***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
RDGDP	0.13***	0.13***	0.13***	0.13***	0.13***	0.13***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
GDPCAP	0.33***	0.33***	0.33***	0.33***	0.33***	0.33***
	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)
NRCA	0.48***	0.48***	0.48***	0.48***	0.48***	0.48***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
COM		1.00***				0.68***
		(0.145)				(0.133)
ALIVE			1.28***			1.03***
			(0.140)			(0.133)
CIT				0.41***		
				(0.040)		
CITwi					0.35***	0.30***
					(0.040)	(0.036)
CITbe					0.15**	0.13**
					(0.030)	(0.026)
MED	0.85***	0.71***	0.49***	0.68**	0.64***	0.28
	(0.203)	(0.198)	(0.192)	(0.196)	(0.192)	(0.179)
SMALL	0.49***	0.33**	0.26	0.36	0.35**	0.06
	(0.173)	(0.171)	(0.165)	(0.168)	(0.167)	(0.155)
MICRO	0.69***	0.48***	0.50***	0.60**	0.55***	0.28*
	(0.189)	(0.186)	(0.179)	(0.182)	(0.180)	(0.167)
DIST	−0.28***	−0.27***	−0.27***	−0.28***	−0.28***	−0.27***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
EPOmemb	0.44***	0.44***	0.44***	0.44***	0.44***	0.44***
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)
YEAR	0.076*	0.080**	0.063	0.07*	0.087**	0.08**
	(0.041)	(0.040)	(0.039	(0.040)	(0.040)	(0.037)
ρ	0.71***	0.69***	0.67***	0.68***	0.70***	0.62***
	(0.019)	(0.020)	(0.021)	(0.021)	(0.021)	(0.023)
n	29,478	29,478	29,478	29,478	29,478	29,478

Note: The dependent variable is the existence of patent equivalent of patent *i* in country *j*. Std. errors in parentheses. ***, ** and * indicate significance at the 1%-, 5%- and 10%-level, respectively. All estimations include 30 industry dummies (not reported).

The first column in Table 3 reports results when only the main country characteristics, *NRCA*, distance, firm size, *YEAR*, EPO membership dummy and industry dummies are included. The results lend support to our main hypotheses from the modeling exercise above. *GDP*, *GROWTH*, *RDGDP*, *GDPCAP* and *NRCA* all influence patenting abroad, significantly and with the expected signs for the parameters. The results from *RDGDP* and *NRCA* indicate that inventors tend to patent more in countries that have technological strengths; generally (*RDGDP*) or specifically (*NRCA*) in the relevant technology field. Also, the parameters of the control variables *DIST* and *EPOmemb* as well as the firm size dummies are significant, and these have the expected signs. *YEAR* has a positive and (weakly) significant coefficient.

Columns 2, 3 and 4 successively introduce patent value indicators. *COM*, *ALIVE* and *CIT* are all strongly positively and significantly correlated with the probability of equivalents. These results hold also when they are included together in column 6. In fact, the estimated parameters are not heavily affected by simultaneously including the three variables. We believe that these results reflect higher values of commercialized, renewed and cited patents. In column 5 and 6 we discriminate between citations between IPC-classes and within IPC-classers. The results indicate that within citations have a higher influence on patent equivalents than do citations between IPC-classes. This may reflect higher imitation risk from citing patents that are technologically close to the cited patent than from technologically distant citing patents.

Table 4 includes *EXPSH* and *PARK95* as additional explanatory variables. Even if gravity variables (*GDP* and *DIST*) are included in our equations, high trade shares may have additional explanatory power. The estimated results indicate that this is the case. Sweden’s export share to her trading partners has significant positive effects on Swedish patenting in these countries. Note that the parameters of the gravity variables (*GDP* and *DIST*) lose size and significance due to inclusion of *EXPSH*, but they remain highly significant. *PARK95* has a positive and highly significant coefficient, indicating that strength of IPRs is important for international patenting. In the context of technology diffusion, this result indicates that improved IPRs facilitate technology diffusion (which may in part or fully compensate for reduced imitation rates).

Table 4. Results of estimations, random effects probit model, with trade

Variable	*1*	*2*	*3*	*4*	*5*	*6*
GDP	0.54***	0.54***	0.54***	0.54***	0.54***	0.54***
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
GROWTH	0.10***	0.10***	0.10***	0.10***	0.10***	0.10***
	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020))
RDGDP	0.11***	0.11***	0.11***	0.11***	0.11***	0.11***
	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
GDPCAP	0.07	0.07	0.07	0.07	0.07	0.07
	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)
NRCA	0.48***	0.48***	0.48***	0.48***	0.48***	0.48***
	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)
COM		1.03***				0.69***
		(0.149)				(0.136)
ALIVE			1.31***			1.05***
			(0.144)			(0.136)
CIT				0.42***		
				(0.042)		
CITwi					0.36***	0.31***
					(0.041)	(0.037)
CITbe					0.15***	0.13***
					(0.030)	(0.027)
MED	0.89***	0.73***	0.51***	0.70***	0.67***	0.30
	(0.208)	(0.204)	(0.197)	(0.201)	(0.198)	(0.184)
SMALL	0.51***	0.34**	0.27	0.37**	0.36**	0.07
	(0.178)	(0.175)	(0.169)	(0.173)	(0.170)	(0.159)
MICRO	0.71***	0.50***	0.52***	0.62***	0.57***	0.30*
	(0.194)	(0.191)	(0.184)	(0.187)	(0.185)	(0.172)
DIST	−0.11***	−0.11***	−0.11***	−0.11***	−0.11***	−0.11***
	(0.040)	(0.040)	(0.040)	(0.041)	(0.041)	(0.041)
EXPSH	5.66***	5.67***	5.66***	5.72***	5.70***	5.70***
	(0.982)	(0.982)	(0.981)	(0.984)	(0.984)	(0.983)
PARK95	0.20***	0.20***	0.20***	0.20***	0.20***	0.20***
	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)
EPOmemb	0.43***	0.43***	0.43***	0.43***	0.43***	0.43***
	(0.053)	(0.053)	(0.054)	(0.054)	(0.054)	(0.054)
YEAR	0.08*	0.08*	0.06	0.08*	0.09**	0.08**
	(0.042)	(0.041)	(0.40)	(0.041)	(0.040)	(0.038)
ρ	0.72***	0.70***	0.68***	0.69***	0.68***	0.63***
	(0.019)	(0.020)	(0.021)	(0.021)	(0.021)	(0.023)
n	27,744	27,744	27,744	27,744	27,744	27,744

Note: The dependent variable is the existence of patent equivalent of patent *i* in country *j*. Std. errors in parentheses. ***, ** and * indicate significance at the 1%-, 5%- and 10%-level, respectively. All estimations include 30 industry dummies (not reported).

In Table 5, we report similar estimations inclusive of patent costs. These results are for the subsample of 20 countries for which patenting costs are available, and are mainly in line with those presented for the larger samples. The exception is that neither *GROWTH* nor *DIST* is significant. Note that patent costs were not available for a series of transition countries with high growth rates. All the other variables enter significantly with the same signs, as reported above. The parameter of *COST* is negative and significant, indicating that patent policies have real important effects.

Table 5. Results of estimations, random effects probit model, with costs

Variable	*1*	*2*	*3*	*4*	*5*	*6*
GDP	0.48***	0.48***	0.48***	0.48***	0.48***	0.48***
	(0.038)	(0.038)	(0.038)	(0.038)	(0.038)	(0.38)
GROW	0.00	0.00	0.00	0.00	0.00	0.00
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
RDGDP	0.07*	0.07*	0.07*	0.07*	0.07*	0.07*
	(0.042)	(0.043)	(0.042)	(0.043)	(0.043)	(0.043)
GDPCAP	0.18	0.18	0.18	0.18	0.18	0.18
	(0.155)	(0.155)	(0.155)	(0.155)	(0.155)	(0.155)
NRCA	0.61***	0.61***	0.61***	0.62***	0.62***	0.52***
	(0.078)	(0.078)	(0.078)	(0.079)	(0.079)	(0.078)
COST	−0.47***	−0.47***	−0.47***	−0.47***	−0.47***	−0.47***
	(0.140)	(0.140)	(0.140)	(0.140)	(0.140)	(0.140)
COM.		1.02***				0.68***
		(0.152)				(0.139)
ALIVE			1.32***			1.05***
			(0.146)			(0.139)
CIT				0.43***		
				(0.042)		
CITwi					0.37***	0.32***
					(0.042)	(0.038)
CITbe					0.15***	0.13***
					(0.030)	(0.028)
MED	0.93***	0.78***	0.56***	0.75***	0.71***	0.35*
	(0.212)	(0.207)	(0.200)	(0.204)	(0.201)	(0.187)
SMALL	0.49***	0.33*	0.26	0.36**	0.35**	0.07
	(0.181)	(0.179)	(0.172)	(0.176)	(0.174)	(0.163)
MICRO	0.70***	0.49**	0.50***	0.60***	0.56***	0.28
	(0.198)	(0.194)	(0.187)	(0.190)	(0.188)	(0.175)
DIST	−0.07	−0.07	−0.07	−0.07	−0.07	−0.07
	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)	(0.050)
EXPSH	7.13***	7.14***	7.12***	7.18***	7.17***	7.16***
	(1.061)	(1.061)	(1.060)	(1.063)	(1.063)	(1.062)
PARK95	0.51***	0.51***	0.51***	0.51***	0.51***	0.51***
	(0.118)	(0.118)	(0.117)	(0.118)	(0.118)	(0.117)
EPOmemb	0.35***	0.35***	0.35***	0.36***	0.35***	0.35***
	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)	(0.089)
YEAR	0.07*	0.08*	0.06	0.07	0.08**	0.07*
	(0.043)	(0.041)	(0.040)	(0.042)	(0.041)	(0.09)
ρ	0.73***	0.71***	0.69***	0.70***	0.69***	0.64***
	(0.019)	(0.020)	(0.021)	(0.021)	(0.021)	(0.023)
n	17,340	17,340	17,340	17,340	17,340	17,340

Note: The dependent variable is the existence of patent equivalent of patent *i* in country *j*. Std. errors in parentheses. ***, ** and * indicate significance at the 1%-, 5%- and 10%-level, respectively. All estimations include 30 industry dummies (not reported). Cost coefficient and its standard deviation is multiplied with 1000.

7. Summary and concluding remarks

We modeled international patenting as the outcome of a strategy where gains and costs were traded off against one another. The model predicts that the number of patent equivalents depends on market size, growth, patent costs and patent specific variables. Our main contribution is that we have tested the model of international patenting using detailed patent level data with several patent value indicators.

Our empirical results support the predictions of the theoretical model. First, more valuable patents – either measured as patent renewal, commercialization or forward citations (both within and between technologies) – have more patent equivalents. Second, the country specific variables have estimates in line with expectations. Market size, economic growth and distance have coefficients with expected signs, and these are not insignificant. Also, indicators of technological rivalry in foreign markets, generally in terms of R&D intensity or relative specialization in the relevant patent classes (NRCA), stimulate international patenting. Finally, IPR policies are consequential on multiple levels. High patenting costs in the host country reduce patenting. The index for patent institutional quality influences international patenting significantly and Swedish patent owners patent more frequently in EPO member countries. However, our results are only applicable to patents owned by individuals and small firms, since the database was restricted to such owners.

Our results are in line with – but go considerably beyond – those of Harhoff *et al.* (2009). They estimate a gravity relationship for patenting among European countries (and for other non-European patent applications in Europe), and find similar results for the aggregate number of patent equivalents between these countries. Equivalents depend positively on market size, and negatively on distance and costs. However, Harhoff et al. (2009) estimate *aggregated* numbers of international patents, and thus were unable to incorporate patent specific characteristics in the same way as we do. They conclude their study by acknowledging an "improvement would be to confirm these results at the patent level" (p. 1434).

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Appendix A

Table A1. Basic information about patent equivalents and costs.

Country	No. of patent equivalents	of which via EPO	EPO member in 1998	Costs available (Helfgott 1993)
United States	224		0	Yes
Canada	41		0	Yes
Brazil	5		0	Yes
EPO	217	217	---	Yes
Germany	210	195	1	Yes
Great Britain	177	174	1	Yes
France	150	148	1	Yes
Netherlands	80	79	1	Yes
Belgium	45	45	1	No
Ireland	34	34	1	No
Switzerland	57	56	1	Yes
Austria	42	41	1	Yes
Italy	87	87	1	Yes
Spain	82	82	1	Yes
Portugal	21	21	1	No
Greece	17	17	1	Yes
Denmark	65	62	1	Yes
Finland	62	58	1	Yes
Luxembourg	3	3	1	Yes
Cyprus	2	2	1	No
Norway	38		0	Yes
Monaco	4		0	No
Russia	16		0	No
Estonia	1		0	No
Poland	21		0	No
Czech Republic	5		0	No
Hungary	2		0	No
Romania	1		0	No
Bulgaria	3		0	No
Japan	141		0	Yes
China	37		0	No
Hong Kong	4		0	No
Taiwan	1		0	Yes
Korea, Rep.	1		0	Yes
Australia	53		0	Yes
New Zealand	1		0	Yes

Table A2. Explanatory variables and hypotheses.

Denotation	Description	Model	Mean	Std. dev.	Expected impact
GDP	Log of GDP in the host country in 1995 (USD)	*Y*	25.8	1.91	+
GROW	Annual growth rate in GDP in the host country 1990−2000 (percent)	*g*	2.56	1.64	+
RDGDP	R&D expenditures per GDP in the host country in 1995 (percent)	*k*	1.46	0.83	+
GDPCAP	Log of GDP per capita in the host country in 1995 (USD, PPP)	*k*	9.85	0.70	+
NRCA	Normalized RCA, see appendix C	*k*	−0.07	0.40	+
COST	Log of total patenting costs in the host country (USD)	*C*	−1.68	0.75	-
PARK95	Unweighted average of scores for five IPR indicators	----	3.81	0.75	+
COM	Dummy which equals 1 if the patent was commercialized, and 0 otherwise	λ	0.61	0.49	+
ALIVE	Dummy which equals 1 if the main patent was still valid in 2004, and 0 otherwise	λ	0.56	0.50	+
CIT	Number of forward citations per five year period between application date and 2007, weighted by IPC classes	λ	0.88	1.49	+
CITwi	Number of forward citations within IPC classes per five year period between application date and 2007, weighted by IPC classes	λ	0.85	1.50	+
CITbe	Number of forward citations between IPC classes per five year period between application date and 2007, weighted by IPC classes	λ	0.47	1.85	+
MED	Dummy which equals one if patent is owned by a medium-sized firm (101−1000 employees)	----	0.13	0.34	+
SMALL	Dummy which equals one if patent is owned by a small firm (101−1000 employees)	----	0.23	0.42	+
MICRO	Dummy which equals one if patent is owned by a micro company (101−1000 employees)	----	0.16	0.37	+
DIST	Log of distance in kilometers between Sweden and the host country	----	7.72	1.01	-
EXPSH	Share of Swedish exports to the country in question (percent)	----	0.04	0.10	+
EPOmemb	Dummy which equals 1 if the country was an EPO-member in 1998	----	0.47	0.49	?
YEAR	Patent application year (range 1985−98)	----	1995	1.65	?
Industry dummies	30 different industry dummies based on IPC (not mutually exclusive)	----	----	----	?

Appendix B.

Inclusion of EPO-patents in the analysis

In the text we excluded EPO-patents since these were counted as patents in each individual country. Inclusion of EPO as an additional entity (in addition to each member country) therefore constitutes double counting of these patents. A dummy variable for whether countries are members of EPO was included, however. Nevertheless, patenting via EPO represents a patent protection decision, giving potential for IPRs in the wider EPO area of jurisdiction. Therefore, protection through EPO is a decision that is different from granted patents in each individual country.

Table B1. Regression results, random effects probit model, including EPO.

Variable	*1*	*2*	*3*	*4*	*5*	*6*
GDP	0.63***	0.63***	0.63***	0.63***	0.63***	0.63***
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
GROW	0.13***	0.13***	0.13***	0.13***	0.13***	0.13***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
RDGDP	0.10***	0.10***	0.10***	0.10***	0.10***	0.10***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
GDPCAP	0.36***	0.36***	0.36***	0.36***	0.36***	0.36***
	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)
NRCA	0.43***	0.43***	0.43***	0.44***	0.44***	0.44***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
COM.		1.10***				0.74***
		(0.159)				(0.146)
ALIVE			1.42***			1.13***
			(0.153)			(0.146)
CIT				0.47***		
				(0.044)		
CITwi					0.40***	0.35***
					(0.043)	(0.040)
CITbe					0.16***	0.14***
					(0.032)	(0.029)
MED	0.95***	0.79***	0.55***	0.75***	0.71***	0.32
	(0.222)	(0.218)	(0.211)	(0.214)	(0.211)	(0.197)
SMALL	0.55***	0.37**	0.29	0.40**	0.39**	0.08
	(0.189)	(0.187)	(0.181)	(0.183)	(0.181)	(0.170)
MICRO	0.77***	0.54***	0.56***	0.67***	0.62***	0.33*
	(0.206)	(0.203)	(0.196)	(0.199)	(0.197)	(0.183)
DIST	−0.32***	−0.32***	−0.32***	−0.32***	−0.32***	−0.32***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
EXPSH	3.86***	3.85***	3.80***	3.93***	3.91***	3.84***
	(1.076)	(1.075)	(1.069)	(1.080)	1.075)	(1.068)
EPO	−2.39***	−2.39***	−2.36***	−2.42***	−2.41***	−2.38***
	(0.498)	(0.498)	(0.495)	(0.498)	(0.498)	(0.495)
YEAR	0.08*	0.08*	0.07	0.08*	0.091**	0.08*
	(0.044)	(0.044)	(0.042)	(0.043)	(0.043)	(0.040)
ρ	0.76***	0.74***	0.72***	0.72***	0.74***	0.67***
	(0.017)	(0.018)	(0.019)	(0.019)	(0.018)	(0.022)
n	29,478	29,478	29,478	29,478	29,478	29,478

Note: The dependent variable is the existence of patent equivalent of patent *i* in country *j*. Std. errors in parentheses. ***, ** and * indicate significance at the 1%-, 5%- and 10%-level, respectively. All estimations include 30 industry dummies (unreported).

Table B1 reports regression results from regressions where EPO patents are included as an observation for each patent (in addition to all the other included observations). A dummy variable for the 867 EPO observations is included in addition to the other variables, but the dummy variable for membership in EPO for individual countries is excluded. Thus, Table B1 resembles Table 4 in all respects except that there are 867 extra observations (with a separate dummy for these), and with no dummy for EPO members. Table B1 does not include the patent quality variable *PARK95* since this is not calculated for EPO. The results are mainly in line with those in the main text. The dummy for EPO is negative and significant. This is consistent with expectations, since granted patents in each individual member country are also included. We also estimated the same models with inclusion of the patent costs variable, and the results are mainly in line with the other variables. They are available upon request.

Appendix C

Derivation of equation 8

$$V(q)_{ij}^{\,patent} - V(q)_{it}^{\,nopatent} = \int_0^\infty \left(1-e^{-q}\right)Y_j e^{g_j s} e^{-rs} ds - \int_0^\infty \left(1-e^{-q}\right)Y_j e^{g_j s} e^{-(r+k)s} ds$$

$$= \left(1-e^{-q}\right)Y_j \int_0^\infty \left(e^{(g_j - r)s} - e^{(g_j - r - k)s}\right)ds$$

$$= \left(1-e^{-q}\right)Y_j \left(\frac{1}{r-g_j} - \frac{1}{r+k-g_j}\right) = \left(1-e^{-q}\right)Y_j \left(\frac{k}{\left(r-g_j\right)\left(r+k-g_j\right)}\right) = C_j$$

$$\rightarrow \left(1-e^{-q}\right) = \frac{C_j\left(r-g_j\right)\left(r+k-g_j\right)}{Y_j k}$$

8) $$q_j{}^* = -\ln\left(1 - \frac{C_j\left(r-g_j\right)\left(r+k-g_j\right)}{Y_j k}\right)$$

Now let $\boldsymbol{\lambda}_i$ denote a vector of patent specific characteristics for patent *i*. These capture the quality indicators described in the text. Write the quality of patent *i* as $q_i = q\boldsymbol{\lambda}_i\boldsymbol{\beta}$. That is, the quality of patent *i* depends on individual specific characteristics, as well as drawing from the random variable *Q*. For patenting to occur, parameter restrictions are such that $q_i > 0$. A patent of quality q_i will therefore be patented in country *j* if q_{ij} exceeds the right hand side of eq. 8. Accordingly, the threshold value for a patent *i* to be patented in country *j* equals:

9) $$q_{ij}{}^* = -\left(\frac{1}{\boldsymbol{\lambda}_i\boldsymbol{\beta}}\right)\ln\left(1 - \frac{C_j\left(r-g_j\right)\left(r+k-g_j\right)}{Y_j k}\right)$$

We assume that $r>g$. This implies that patentees' discounting rates from profits in the relevant countries, net of growth rates, are positive. Therefore $0<[1/(r\text{-}g)\text{-}1/(r+k\text{-}g)]<1$. Given these assumptions, the derivations reported in *Lemma* in the main text hold. Given that the last term in the parenthesis is less than one, expressions 8 and 9 give a positive threshold value for the quality of inventions for which only higher valued inventions are patented. We also assume that patent costs relative to GDP are smaller than the difference between effective discounting rates, with and without patenting, $C/Y<[1/(r-g)-1/(r+k-g)]$. If this is not fulfilled, no inventions will be patented.

Appendix D

RCA and normalized RCA

Let X_{sj} denote country *j*'s number of patents in IPC class *s*. The *RCA* is given as:

$$RCA_{sj} = \frac{X_{sj} \Big/ \sum_s X_{sj}}{\sum_j X_{sj} \Big/ \sum_s \sum_j X_{sj}}$$

RCA_{sj} therefore denotes country *j*'s specialization in technology class *s*, relative to the global specialization in the same technology class. The RCA index varies from zero to infinity and is generally asymmetric. We normalized it to $(RCA\text{-}1)/(RCA\text{+}1)$ to arrive at a symmetric measure. Each patent according to its IPC class is therefore assigned a value of the normalized RCA index for each country. When a patent was assigned to more than one technology class, we used an average.

The advantage of using the NBER patent database to construct the above index is that, since the database is based on patents granted by USPTO, it is fairly robust to international differences in patent institutions. We therefore expect the index to provide a fairly good impression of countries' technological specialization vis-à-vis the patent in question.

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[1] See e.g. Maskus (2000), Birdsall, Rodrik and Subramanian (2005), Helpman (1993) and Branstetter et al. (2011).

[2] Multilateral cooperation in the field of IPRs was extended after the Paris convention with an increasing number of member states and several new agreements, e.g. Scotchmer (2004) or Maskus (2000). In Hoekman and Kostecki (1995) the road from GATT to the WTO (and the TRIPS) is discussed and analyzed. Japan, Europe and the U.S. have the largest patent institutions internationally, in terms of number of patents. Traditionally, the three areas have differed according to national priorities. However, although they have in recent years converged considerably, there are still some differences (see e.g. Harison 2008).

[3] PCT = Patent Cooperation Treaty. The PCT system does not provide for the grant of an international patent, but it: 1) simplifies the process of filing patent applications in individual countries; 2) delays the expenses associated with applying for patent protection in other countries; and 3) allows the inventor more time to assess the commercial viability of his invention. Under the PCT, an inventor can file a single international patent application for an invention in one language with one patent office in order to simultaneously seek protection in up to 148 countries throughout the world.

[4] If a patent is granted by EPO, the national patent offices always have to follow this decision.

[5] Developments in the USA and Japan reflect the size of these countries' home markets.

[6] A related, but different literature focuses on licensing and transfers of patent rights. Also elements of this literature studies international trade in patent rights. Burhop and Wolf (2013) apply this approach on historical German data. Akcigit, Celik and Greenwood (2013) construct a model for the market for patents and test it on empirical data. Related studies are Serrano (2010) and Gans and Stern (2010). An overview is provided in Arora and Gambardella (2010).

[7] Abrams *et al.* (2013) and Maurseth (2005) qualify the assumption that forward patent citations signal higher value of a patent. Abrams *et al.* argue that defensive but economic important patents are cited less than other patents. Maurseth argues that patent citations within narrowly defined technology classes signal rival patents that render the cited patent obsolete.

[8] Abrams *et al.* (2013) however, argue that many valuable patents are defensive and that these are cited less than other patents. Defensive patents are not likely to be commercialized. Related is Svensson (2012).

[9] In 1998, 2,760 patents were granted in Sweden. 776 of these were granted to foreign firms, 902 to large Swedish firms with more than a 1,000 employees, and 1,082 to Swedish individuals or firms with less than a 1,000 employees. In a pilot survey carried out in 2002, it turned out that large Swedish firms refused to provide information on individual patents. Furthermore, it proved very difficult to persuade foreign firms to answer questionnaires about patents. The foreign firms are almost always large multinationals. However, the sample selection in our data is not a problem insofar as the conclusions are drawn for small firms and individual inventors located in Sweden.

[10] Of the 20 percent non-respondents, 10 percent of the inventors had outdated addresses, 5 percent had correct addresses but did not respond, and the remaining 5 percent refused to participate. The only information we have about the non-respondents is the IPC-class of the patent and the region of the inventors. For these variables, there was no systematic difference between respondents and non-respondents.

[11] This average number of equivalents is the same as for EPO-patents in general (van Zeebroeck 2011).

[12] For example, the mean number of patent equivalents for an invention with a patent equivalent in the U.S. is 5.8. A patent with an equivalent in Estonia (or Romania) occurred only once. These had 24 equivalents (both for the Estonian and the Romanian cases).

[13]. In Sweden patent owners must pay an annual renewal fee to the relevant patent office in order to keep their patents in force. The patent expires if the renewal fee is not paid in any single year. Thus, the patent owner has an option to renew the patent every year.

[14] For similar formulations of the above relationships, see Eaton and Kortum (1996) or Grossman and Helpman (1991a or 1991b, chapter 4).

[15] It is not difficult to generalize to a reduction in imitation rates from any $k^{nopatent}$ to any k^{patent}. Also, it is a simple task to introduce a statutory maximum lifetime for patents. This complicates the derived empirical specifications without adding clarity.

[16] Eaton and Kortum (1996) propose an exponential distribution. The average step of an invention can then be parameterized as $1/\theta$.

[17] We lack country data for Taiwan, for which there is one granted patent. Some results included in the appendix are also for EPO-patents in addition to granted patents in the individual EPO member countries. This expanded the data set by 867 extra observations, to 30,345.

[18] We use 1995 as the year for level variables since patents granted in 1998 were applied for in previous years. We use growth in the period 1990 to 2000 to capture growth experience *and* expectations at the granting date.

[19] But high levels of R&D in a country could also reflect economic conditions in the country that are favorable to demand for the patented invention.

[20] GDP per capita can also, however, reflect influence from the demand side, for instance because of non-homothetic preferences.

[21] Another problem is that the cost data seems to be old. The patents covered by our database were granted in 1998, but applied for the 1992−96 period. The costs reported in Helfgott (1993) are therefore somewhat low as compared to the costs faced by the applicants in our dataset (due to inflation), but does not constitute a serious problem as the application years are not far from 1993. Further, we do not know whether or not they changed proportionally to each other. A second problem is how patent costs via EPO are reported. These should include validation costs in individual countries to reflect the costs faced by the Swedish firms when applying for patent equivalents in other EPO member countries. However, we do not have access to these validation costs.

[22] The index is available for 32 of the 34 countries in our sample. We lack observation of this index for Estonia and Macedonia. The dataset is then reduced to 867*32 = 27,744 observations.

[23] *EXPSH* is taken from the COMTRADE database and supplemental data for Hong Kong from Statistics Sweden. This variable is included at the cost of observations for Monaco.

[24] Note that the patentee does not know the actual examination period at the time of application. In the literature, inexperienced patentees and requests for accelerated search have been identified as correlated with patent consideration time at the patent offices (see van Zeebroeck and van Pottelsberghe 2011).

[25] We exclude patents granted by EPO since they are also reported as patents in individual EPO countries. See appendix B for estimations where these applications were included.