IFN Working Paper No. 934, 2012

Micro Evidence on International Patenting

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October 2012

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 Swedish small 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 and indicators of technological rivalry and market size in the host market.

JEL classification: O33, O34

Keywords: International patenting, host country characteristics, patent value

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The authors would like to thank Nicolas van Zeebroeck, Iain Begg and the seminar participants at the ZEW Workshop on Patents and Innovations in Mannheim, EPIP-conference in Brussels and ETSG-conference in Copenhagen for insightful comments. Roger Svensson gratefully acknowledges financial support from the Marianne and Marcus Wallenberg Foundation.

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 revolving 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. With this approach, international patenting signals international technology diffusion and that the IPR owners expect their technology to have a market abroad. A patent in a specific country protects the inventor 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.

During the last decades, there has been 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. But still, most patents are patented in one or a few countries only.

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[1] See e.g. Maskus (2000), Birdsall *et al.* (2005), Helpman (1993) and Branstetter *et al.* (2011). Jakobsson and Segerstrom (2012) provide a short survey of the academic literature.

The purpose of this study is to analyze the international patenting strategy of small firms and inventors. A theoretical model based on 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. It contains information on patent equivalents, some patent value indicators and characteristics of the firms and the inventors. This database is complemented with host country characteristics. We find that the results in the empirical estimations are in accordance with the model's predictions.

Our topic is important. First, as noted, international patenting provides one (of several) channels 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 method and hypotheses for explanatory variables are set up in section 5. The parameters of the model are empirically estimated in section 6, and the final section concludes.

2. International patenting

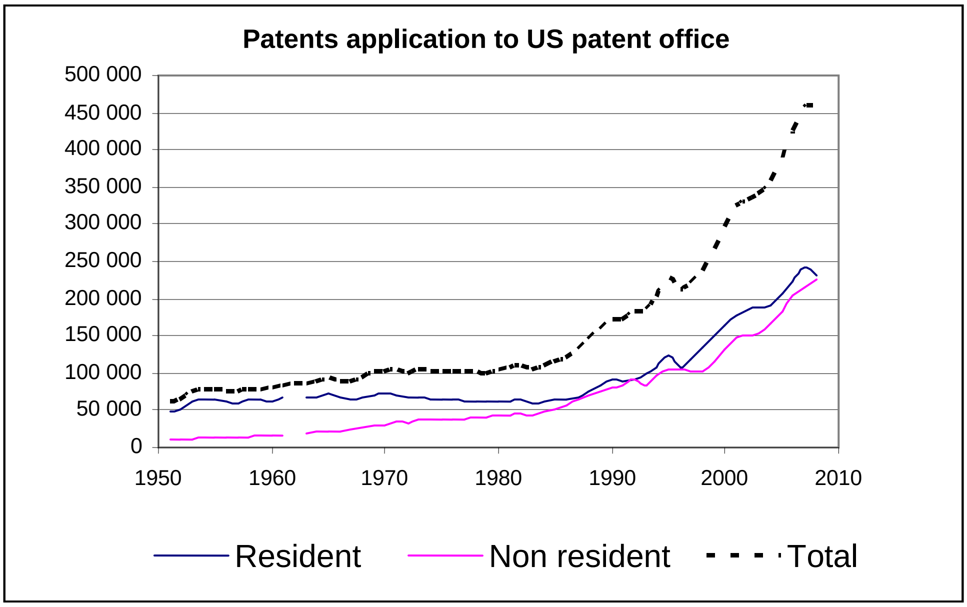
IPR protection has traditionally been the domain of nation states. But international treaties ─ from the Paris convention in 1883 to the TRIPS agreement in 1995 and several more recent agreements ─ have dictated convergence in IPR institutions. International patentees are guaranteed national treatment by increasingly similar IPR institutions throughout the world.[2] In Europe, the European Patent Office (EPO)

[2] Multilateral co-operation 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). OECD (2004) discusses trends and policy challenges in the world's patent system. In Hoekman and Kostecki (1995) the road from GATT to the WTO (and the TRIPS) is discussed and analyzed. For a critical discussion about reforms in the U.S. patent system, see Jaffe and Lerner (2004).

supplements national patent offices and grants patents for all or some member countries. Thus, international patenting is facilitated by institutional reforms.[3]

The EPO-system is much more fragmented than the U.S. and Japanese systems (van Pottelsberghe de la Potterie 2009 and 2010; van Pottelsberghe de la Potterie and Francois 2006). The costs for EPO-patents are considerably higher, since patents have to be validated and subsequently renewed in the member states where patent protection is sought.[4] Furthermore, there is no unitary European litigation court.

Figure 1. Patent applications to U.S. patent office



Source: WIPO (2011).

International patenting has increased in importance in recent years. Figure 1 graphs the number of patent applications from residents and non-residents to the U.S. patent office (USPTO) from 1950 onwards. While patenting stagnated until the mid 1980s there was a large increase thereafter, both from residents and from non-residents.[5] For the world

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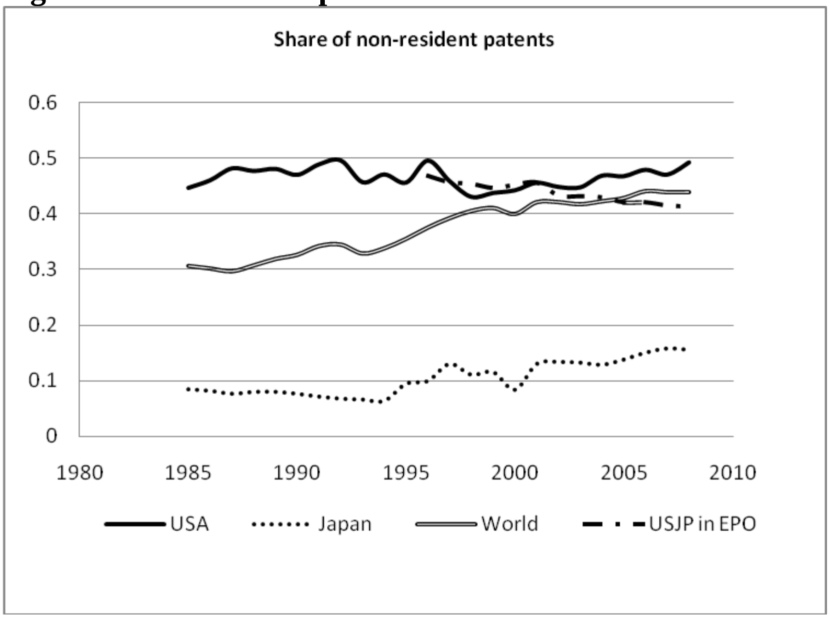
[3] Japan, Europe and the U.S. have the largest patent institutions internationally, in terms of number of patents. Traditionally, the three systems have differed according to national priorities. However, they have converged considerably in recent years. But there are still some differences (see e.g. Harison 2008).

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

[5] The stagnating (and, for the case of domestic patent applications falling) trend spurred debates whether R&D had entered a phase of decreasing returns and slowing productivity growth. Griliches (1989) pointed at institutional weaknesses in the patent system to explain the falling trend. Subsequent institutional reforms (both in the U.S., in Europe, in other countries and multilaterally) may lent support to Griliches' view. Kortum (1993), on the other hand, has argued that developments in the number of patent applications — both from residents and non-residents — could be explained by economic developments. He argued that increased market sizes for new technologies and therefore profitability from innovation stimulated more R&D per patent. The later increase in US patenting, on the other side, is

economy, the number of patent families ─ i.e. the number of patented inventions, including their international patent equivalents ─ has increased by around 80 percent between 1990 and 2006 (WIPO 2011).

Figure 2. Non-resident patents



Source: WIPO (2011).

Figure 2 shows developments of the share of non-resident patent applications for all countries, for the U.S. and Japan as well as for U.S. and Japanese patents in EPO.[6] Figures 1 and 2 indicate that non-residents slowly have increased their share of patenting in the major economies.

Our discussion above indicates that international patenting is of as great importance as national patenting. Evenson (1984) discussed trends in international patenting. He showed that there are comparative advantage patterns in invention 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.[7] Eaton and Kortum (1996) and McCalman (2005) use international patenting and international copyrights to make inferences about international technology diffusion (McCalman for the case of Hollywood movies).

explained by changes in management of research (Kortum and Lerner 1999). The effects of patent institutional reform and the TRIPS agreement from 1995 onwards are still up for debate.

[6] Figures are different for the EPO, since the member countries have changed over time. Therefore, internationalization is demonstrated most clearly with the use of large outside countries.

[7] Evenson (1984) provides support for the pessimistic view that the number of inventions per scientist was on a declining trend in the early 1980s.

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. 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.

From another perspective, international patenting has been used as an indicator of the value of the patented invention. Putnam (1996) and Lanjouw *et al.* (1996) are pioneering contributions. Several studies have found that the size of the patent family is positively related with patent or firm value (Schmoch *et al.* 1988; Lanjouw and Schankerman 2001; Harhoff *et al.* 2002). This is logical. Only those inventions with sufficiently high values will be patented abroad, given the high costs to file and renew the patents in many countries. The literature on patent value indicators is recently surveyed by van Zeebroeck (2011) and van Zeebroeck and van Pottelsberghe de la Potterie (2011).

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. Related is Branstetter *et al.* (2006) who investigate technology transfers within U.S. multinationals as a function of changes in other countries' IPR regimes.

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.[8] Information about inventors, applying firms and their addresses as well as application dates for each patent, was received from the Swedish Patent and Registration Office (PRV). Thereafter, a questionnaire was sent out to the

[8] 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 1 000 employees, and 1 082 to Swedish individuals or firms with less than 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. The sample selection in our data is not a problem however, as long as the conclusions are drawn for small firms and individual inventors located in Sweden.

inventors of the patents. 867 (out of 1 082) inventors filled in 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.[9]

The questionnaire asked the inventors about the 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 and forward citations from the Espacenet (2010) website.

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. 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.

In total there are patent equivalents in 35 different countries in the data set. The frequency for each country is shown in Appendix A, Table A1. The Swedish patents had 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 1104 individual patents in the EPO-member countries, i.e. on average 5.1 individual patents per EPO-patent.[10] 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

[9] Of the 20% non-respondents, 10% of the inventors had outdated addresses, 5% had correct addresses but did not respond, and the remaining 5% 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.

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

countries.[11] Van Zeebroeck and van Pottelsberghe de la Potterie (2011) have shown that there is a strong positive correlation between market size and the probability that an EPO-patent will be validated in that country.

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

Categories		Patent equivalents abroad		No. of patents per category	Average No. of equivalents	Chi-square test
		Yes	No			
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.

The skewed country distribution of patents above indicates that country characteristics are important for international patenting. 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,

[11] 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. This had 24 equivalents (both for the Estonian and the Romanian cases).

there is no uniform relationship between firm size and equivalents. Micro companies have as many equivalents as small firms.

In line with the previous literature (Schmoch *et al.* 1988; Lanjouw and Schankerman 2001; Harhoff *et al.* 2002), 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 that are commonly used as indicators of patent value. Such variables include patent renewal, forward citations and commercialization, all of which are related to the private or social value of patents (see the survey by van Zeebroeck, 2011, or van Zeebroeck and van Pottelsberghe de la Potterie, 2011).

Renewal behavior has often been used to infer about the private value (distributions) of patents.[12] Patents which had equivalents were considerably more likely to still be valid (i.e. still alive) in 2004, than those without. 51 percent of the patents 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 4.0 equivalents on average 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 reason for this is that patents that are cited by subsequent patents are considered as basic inventions which are useful for development of new knowledge. Many studies have also indicated higher private value of patents with many forward citations (see e.g. Jaffe and Trajtenberg 2002). In addition however, there may be other reasons why this correlation is so high. The citations are mostly added by independent patent examiners at the patent offices. When a Swedish patent has equivalents abroad the patent 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.

[12] See e.g. Pakes and Schankerman (1984), Pakes (1986), Schankerman and Pakes (1986), Pakes and Simpson (1989) and Schankerman (1998). In Sweden and most other countries, 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. The option for further renewal is acquired by renewing the patent at each mandatory date.

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 strongly rejects that there is independence between commercialization and equivalents.

4. A model set up for international patenting

Our model is a slightly simplified and modified version of Eaton and Kortum (1996). Their model is a full fledged international general equilibrium growth model in which international patenting plays an important role. In Eaton and Kortum's model, R&D in different countries 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. This risk 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 theory basis for our empirical specification of international patenting. Our available data are micro data and this allows us to formulate patent owners' choice about where to patent.

The model is a quality ladder model of innovation à la Grossman and Helpman (1991). 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. Inventions improve the quality of an intermediate with a specific percentage amount, which is defined as the size of the invention. An invention improves on the quality of an intermediate so 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 randomness of invention size makes the patenting decision heterogeneous. Inventions that are large may be patented widely; inventions that are small may only be patented in the home country of the owner.

Producers of a newly invented intermediate charge the highest possible price at which production without that invented intermediate is unprofitable (Bertrand competition). 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* so that the leading firm in the market marginally undercuts the optimal price charged by the firm with the next highest quality. This 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) $$\pi_v = p_v X_v - w X_v = \frac{e^{q_v} wY}{e^{q_v} w} - w \frac{Y}{e^{q_v} w} = \left(1 - e^{-q_v}\right) Y$$

Equation 4 relates profitability of patenting to market size. This proves to be an important empirical regularity.[13]

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

A patent reduces the probability that the invention will be imitated in any period during the patents lifetime from k to zero. For simplicity we assume that patents last forever.[14] 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 at time t are therefore:

$$5)\qquad V(q)_{jt}^{nopatent} = \int_t^{\infty} \left(1 - e^{-q}\right) Y_{jt} e^{g_j s} e^{-(r+k)s} ds$$

$$6)\qquad V(q)_{jt}^{patent} = \int_t^{\infty} \left(1 - e^{-q}\right) Y_{jt} e^{g_j s} e^{-rs} ds$$

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

$$7)\qquad V(q^*)_{jt}^{patent} - V(q^*)_{jt}^{nopatent} = C_{jt}$$

determines the threshold quality level q^* such that innovations of higher quality are patented while those with lower qualities are not. Therefore the threshold value q_{jt}^* for a patent to be patented in country j at time t is given in equation 8. The derivation of it is presented in Appendix C.

$$8)\qquad q_{jt}^* = -\ln\left(1 - \frac{C_{jt}\left(r - g_j\right)\left(r + k - g_j\right)}{Y_{jt} k}\right)$$

It is seen from equation 8 that the threshold value q_{jt} 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, $\boldsymbol{\lambda_i}$, and the realization of a random variable Q drawn from a probability distribution so that $P(Q<q) = F(q)$.[15] We formulate the size of an invention i as the product of realizations

[14] It is easy 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.

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

of Q and patent specific characteristics captured by the vector $\boldsymbol{\lambda}_{\mathbf{i}}$ with coefficient vector $\boldsymbol{\beta}$, $q_{ijt} = q\boldsymbol{\lambda}_i\boldsymbol{\beta}$. For patenting to occur it must be that, $q_{ijt}>0$, which imposes parameter restrictions in the vector $\lambda_i\boldsymbol{\beta}$. Then the threshold realization of Q for a patent i to be patented in country j is:

9) $$q_{ijt}* = -\left(\frac{1}{\boldsymbol{\lambda}_{\mathbf{i}}\boldsymbol{\beta}}\right)\ln\left(1-\frac{C_{jt}(r-g)(r+k-g)}{Y_{jt}k}\right)$$

The following results are easily derived:

Lemma

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

$$\frac{dq_{ijt}*}{dC_{jt}} > 0$$

$$\frac{dq_{ijt}*}{dY_{jt}} < 0$$

$$\frac{dq_{ijt}*}{dg_{jt}} < 0$$

$$\frac{dq_{ijt}*}{dk_{jt}} < 0$$

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

Generally, the quality of patented inventions has unknown distributions. The exact functional form of the probability to patent is therefore not known. A rough approximation will be to analyze the binary choice (to patent or not) as:

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

Above, PQ_{ijt} 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) $$P(PQ_{ijt} = 1) = f(\mathbf{T}_{jt}\alpha + \boldsymbol{\lambda}_{it}\beta)$$

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

Our empirical strategy is to estimate varieties of the above model. In our dataset, we have information on whether a patent has been granted in any of the 35 countries (see Appendix A, Table A1). On the basis of this, we create an expanded dataset consisting of 867*34 = 29 478 observations.[16] The dependent binary variable is whether the owner has patent protection for patent i in country j. Accordingly, we will use a model with a binary dependent variable to estimate how various explanatory variables are related to the patent applications in individual countries. Our data set is two dimensional, along the patent dimension (i.e. different patents are applied for in a given country) and along the country dimension (one patent can be applied for different countries). Thus the dataset has panel data characteristics. 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. Remaining noise is captured by u_{ij}.

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

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

Variables derived from the model

GDP reflects market size in the host country and *GROWTH* captures GDP growth in the host country. 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).
- *GDPCAP*. GDP per capita may reflect the technological level of the host country and a higher probability of being imitated (from World Development Indicators).[17]
- *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. The data was taken from the NBER patent data base (Hall *et al.* 2011). The formula is given in Appendix D.

In line with the theory, we include total patent costs in the host country, *COST*. There is no patent cost index for all countries. A reason is that costs of patenting depend on several components. One is the filing costs. Very often (official) translation of the patent documents is required. If so, this adds a new cost component. Often, patentees use patent agencies for handling national patent offices which adds costs that may be diverse. Futhermore, annual renewal costs are added if the patent is granted. In most countries such renewal costs are low but increasing with the age of the patent. In Europe, patent protection can be applied in many countries via EPO. If so, the patent 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. We have chosen to use the patent costs from the survey

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

by Helfgott (1993). A problem with Helfgott's cost data is that it covers only 20 of our 34 countries (see Table A1).[18] We report separate estimation results when *COST* is included.

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 would imply a higher probability of patenting the invention in any market.

- *ALIVE* is a dummy variable for whether the patent was still valid in 2004.
- *COM* is a dummy variable whether the invention was commercialized.
- *CIT* measures the number of forward citations per five-year period.

Hall *et al*. (2002) argue that patents that are cited across many technology fields are general and that such patents 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 higher private and social value of the patented invention. Therefore, we discriminate between intra-technology patent citations and inter-technology patent citations with the two variables *CITwi* and *CITbe* in most estimations.

We have reason 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 not clear in which direction causality runs between our right-hand value indicators and patent equivalents. Therefore, we include the patent value indicators with caution and introduce them successively in separate estimations.

[18] Another problem is that the cost data is old. The patents covered by our database were granted in 1998, and where therefore applied for in the mid-1990s. The costs reported in Helfgott (1993) are therefore too low as compared to the costs faced by the applicants in our dataset (due to inflation). Furthermore, we do not know whether they changed proportionally to each other or not. 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.

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 (less goods are exported there). But it may also be that distance indicates higher (non-formal) costs of patenting in the country. The inventor may have to travel there. Also languages and cultures may be more different across long distances.

EXPSH is measured as Sweden's export share with the country in question.[19] We expect a high Swedish export share to indicate an important market for Swedish producers and therefore 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 according to Breschi *et al.* (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 they 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 shorter time for consideration at the patent office. One interpretation is that patents that are under consideration for longer periods are more minor and dubious than patents that are granted after a short period of consideration. If this is the case, patents that were applied

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

for early would have lower private values.[20] Another interpretation of long consideration is that the invention is complex.

6. Results of the empirical estimations

Tables 3 through 5 present the empirical results estimated by the random effects probit model. They report results from estimations where the dependent variable is patent equivalents in individual countries.[21] 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 bottom of the tables) 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 (see 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 data.

The first column in Table 3 reports results when only main country characteristics, *NRCA*, firm size and industry dummies are included. The results lend support to our main hypotheses from the modeling exercise above. *GDP*, *GROW*, *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 *EPO* as well as the firm size dummies are significant and have the expected signs.

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 7. In fact, the estimated parameters are not heavily affected by including the three variables simultaneously. We believe that these results reflect higher values of commercialized,

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[20] 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 Zeebroek *et al.* 2011).

[21] That is, we exclude patent applications to EPO since they are also reported as patents in individual EPO countries. See appendix B for estimations where these applications were included.

renewed and cited patents. The results for divided citation variables in columns 5 and 7 indicate that citations between IPC-classes have a higher influence on patent equivalents than citations within IPC-classes (though the difference is not significant).

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

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*
GDP	0.67***	0.67***	0.67***	0.67***	0.67***	0.67***	0.67***
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
GROWTH	6.68***	6.67***	6.66***	6.68***	6.68***	6.68***	6.65***
	(1.633)	(1.634)	(1.633)	(1.634)	(1.634)	(1.634)	(1.633)
RDGDP	0.13***	0.13***	0.13***	0.13***	0.13***	0.13***	0.13***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
GDPCAP	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***	0.32***
	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)	(0.045)
NRCA	0.47***	0.47***	0.47***	0.47***	0.47***	0.47***	0.47***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
COM		1.00***					0.76***
		(0.145)					(0.137)
ALIVE			1.29***				1.10***
			(0.140)				(0.136)
CIT				0.53***			
				(0.093)			
CITwi					0.49***		0.45***
					(0.098)		(0.088)
CITbe					1.42**		1.27**
					(0.623)		(0.556)
MED	0.87***	0.72***	0.50***	0.83***	0.82***	0.85***	0.39**
	(0.203)	(0.199)	(0.192)	(0.200)	(0.200)	(0.203)	(0.184)
SMALL	0.50***	0.34**	0.26	0.46***	0.45**	0.49***	0.12
	(0.173)	(0.170)	(0.165)	(0.171)	(0.171)	(0.173)	(0.160)
MICRO	0.70***	0.49***	0.51***	0.66***	0.62***	0.69***	0.31*
	(0.190)	(0.186)	(0.180)	(0.187)	(0.188)	(0.189)	(0.173)
DIST	−0.28***	−0.28***	−0.28***	−0.28***	−0.28***	−0.28***	−0.28***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
EPO	0.44***	0.44***	0.44***	0.44***	0.44***	0.44***	0.44***
	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.051)	(0.052)
YEAR						0.08*	0.09**
						(0.041)	(0.037)
ρ	0.71***	0.69***	0.67***	0.70***	0.70***	0.71***	0.64***
	(0.019)	(0.020)	(0.021)	(0.020)	(0.020)	(0.019)	(0.022)
n	29 478	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%-significant level, respectively. All estimations include 30 industry dummies (not reported).

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 7. In fact, the estimated parameters are not heavily affected by including the three variables simultaneously. We believe that these results reflect higher values of commercialized, renewed and cited patents. The results for divided citation variables in columns 5 and 7 indicate that citations between IPC-classes have a higher influence on patent equivalents than citations within IPC-classes (though the difference is not significant).

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

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*
GDP	0.58***	0.58***	0.58***	0.58***	0.58***	0.58***	0.58***
	(0.033)	(0.033)	(0.032)	(0.033)	(0.033)	(0.33)	(0.033)
GROWTH	5.82***	5.81***	5.80***	5.80***	5.80***	5.83***	5.76***
	(1.663)	(1.663)	(1.662)	(1.663)	(1.663)	(1.663)	(1.663)
RDGDP	0.15***	0.15***	0.15***	0.15***	0.15***	0.15***	0.15***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
GDPCAP	0.23***	0.23***	0.23***	0.23***	0.23***	0.23***	0.23***
	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)	(0.047)
NRCA	0.46***	0.46***	0.46***	0.46***	0.46***	0.46***	0.46***
	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)
COM		1.02***					0.73***
		(0.148)					(0.136)
ALIVE			1.31***				1.10***
			(0.144)				(0.135)
CIT				0.58***			
				(0.061)			
CITwi					0.51***		0.47***
					(0.067)		(0.060)
CITbe					1.23***		1.07***
					(0.300)		(0.266)
MED	0.89***	0.74***	0.52***	0.72***	0.73*	0.88***	0.31*
	(0.208)	(0.203)	(0.196)	(0.200)	(0.200)	(0.208)	(0.183)
SMALL	0.51***	0.35**	0.27	0.46***	0.43**	0.51***	0.11
	(0.177)	(0.175)	(0.169)	(0.171)	(0.171)	(0.177)	(0.158)
MICRO	0.72***	0.50***	0.52***	0.58***	0.54***	0.71***	0.34
	(0.194)	(0.190)	(0.184)	(0.187)	(0.187)	(0.194)	(0.172)
DIST	−0.17***	−0.17***	−0.17***	−0.17***	−0.17***	−0.17***	−0.17***
	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)
EXPSH	4.69***	4.60***	4.59***	4.67***	4.67***	4.59***	4.65***
	(1.122)	(1.122)	(1.121)	(1.123)	(1.124)	(1.122)	(1.123)
EPO	0.48***	0.49***	0.49***	0.49***	0.49***	0.49***	0.49***
	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
YEAR						0.08*	0.107***
						(0.042)	(0.377)
ρ	0.72***	0.70***	0.68***	0.69***	0.69***	0.72***	0.63***
	(0.019)	(0.020)	(0.021)	(0.020)	(0.021)	(0.019)	(0.023)
n	28 611	28 611	28 611	28 611	28 611	28 611	28 611

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%-significant level, respectively. All estimations include 30 industry dummies (not reported).

Table 4 includes *EXPSH* as an additional explanatory variable. 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 positive and significant effects on Swedish patenting in these countries. Note that the parameters of the gravity variables (*GDP* and *DIST*) loose size and significance due to inclusion of *EXPSH*, but are still all highly significant. In the estimations reported in Table 4, the differences between the parameters of *CITbe* and *CITwi* are significant.

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

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*
GDP	0.52***	0.52***	0.52***	0.52***	0.52***	0.52***	0.52***
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.40)
GROW	-1.89	-1.92	-1.95	-1.91	-1.96	-1.88	-2.03
	(3.463)	(3.464)	(3.460)	(3.463)	(3.464)	(3.463)	(3.462)
RDGDP	0.17**	0.17***	0.17**	0.17***	0.18***	0.17***	0.17***
	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
GDPCAP	0.66***	0.67***	0.66***	0.67***	0.67***	0.67***	0.67***
	(0.101)	(0.101)	(0.101)	(0.101)	(0.101)	(0.101)	(0.101)
NRCA	0.56***	0.57***	0.56***	0.56***	0.57***	0.565***	0.57***
	(0.077)	(0.078)	(0.078)	(0.078)	(0.078)	(0.078)	(0.078)
COST	−0.37***	−0.37***	−0.37***	−0.37***	−0.37***	−0.37***	−0.37***
	(0.131)	(0.131)	(0.131)	(0.131)	(0.131)	(0.131)	(0.131)
COM.		1.02***					0.73***
		(0.153)					(0.140)
ALIVE			1.34***				1.12***
			(0.148)				(0.140)
CIT				0.55***			
				(0.098)			
CITwi					0.52***		0.48***
					(0.069)		(0.063)
CITbe					1.27***		1.10***
					(0.308)		(0.275)
MED	0.95***	0.80***	0.58***	0.92***	0.78***	0.94***	0.36*
	(0.214)	(0.209)	(0.202)	(0.211)	(0.205)	(0.214)	(0.189)
SMALL	0.51***	0.35*	0.27	0.47***	0.434**	0.50***	0.11
	(0.183)	(0.180)	(0.174)	(0.180)	(0.176)	(0.183)	(0.163)
MICRO	0.71***	0.50**	0.52***	0.67***	0.53***	0.71***	0.23
	(0.200)	(0.197)	(0.189)	(0.197)	(0.193)	(0.200)	(0.178)
DIST	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02	−0.02
	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)
EXPSH	7.15***	7.16***	7.14***	7.19***	7.25***	7.15***	7.24***
	(1.325)	(1.325)	(1.323)	(1.326)	(1.328)	(1.325)	(1.326)
EPO	0.62***	0.62***	0.62***	0.62***	0.62***	0.62***	0.62***
	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)	(0.071)
YEAR						0.07*	0.10***
						(0.043)	(0.039)
ρ	0.73***	0.72***	0.69***	0.72***	0.70***	0.73***	0.64***
	(0.019)	(0.020)	(0.021)	(0.019)	(0.020)	(0.019)	(0.023)
n	17 340	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%-significant level, respectively. All estimations include 30 industry dummies (not reported).

In Table 5, we report similar estimations where patent costs are included. These results are for a subsample of 20 countries for which patenting costs are available. The results in Table 5 are mainly in line with those presented for the larger samples, except that neither *GROW* 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.

7. Summary and concluding remarks

We modeled international patenting as the result of a strategy where gains and costs were traded off against each other. The model predicts that the number of patent equivalents depend on market size, growth, patent costs and patent specific variables.

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 which also are significant. 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 matter. High patenting costs reduce patenting.

Our results are in line with 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, negatively on distance and negatively on costs. Harhoff *et al.* (2009) estimate aggregated numbers of international patents, however. Therefore they were not able to include patent specific characteristics in the same way as we do. They conclude that 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 2000 (USD)	*Y*	26.0	1.83	+
GROW	Annual growth rate in GDP in the host country 1990-2000 (percent)	*g*	-1.48	0.17	+
RDGDP	R&D expenditures per GDP in the host country in 2000 (percent)	*k*	1.44	0.84	+
GDPCAP	Log of GDP per capita in the host country in 2000 (USD, PPP)	*k*	10.0	0.68	+
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	-
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	λ	0.50	1.00	+
CITwi	Number of forward citations within IPC classes per five year period between application date and 2007	λ	0.45	0.92	+
CITbe	Number of forward citations between IPC classes per five year period between application date and 2007	λ	0.05	0.20	+
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	+
EPO	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 observations of patenting through EPO since these were counted as patents applied for in each individual country. Inclusion of EPO as an additional entity (in addition to each member country) therefore involves double counting of these patents. A dummy variable for whether countries are members in EPO was included, however. Nevertheless, patenting via EPO represents a patent application decision, giving potential for IPRs in the wider EPO area of jurisdiction. Therefore, application through EPO is a decision that is different from patent application to each individual country.

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

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*
GDP	0.70***	0.70***	0.70***	0.70***	0.70***	0.70***	0.70***
	(0.021)	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)	(0.021)
GROW	6.96***	6.95***	6.93***	6.95***	6.96***	6.96***	6.93***
	(1.640)	(1.641)	(1.640)	(1.640)	(1.640)	(1.640)	(1.640)
RDGDP	0.09***	0.09***	0.09***	0.09***	0.09***	0.09***	0.09***
	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
GDPCAP	0.43***	0.43***	0.42***	0.426***	0.43***	0.43***	0.43***
	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
NRCA	0.44***	0.44***	0.44***	0.44***	0.44***	0.44***	0.44***
	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)	(0.067)
COM.		1.08***					0.82***
		(0.156)					(0.147)
ALIVE			1.40***				1.20***
			(0.151)				(0.147)
CIT				0.59***			
				(0.101)			
CITwi					0.54***		0.49***
					(0.106)		(0.095)
CITbe					1.53***		1.36**
					(0.675)		(0.604)
MED	0.94***	0.78***	0.55***	0.91***	0.89***	0.93***	0.42**
	(0.219)	(0.214)	(0.207)	(0.215)	(0.215)	(0.218)	(0.200)
SMALL	0.54***	0.37**	0.28	0.50***	0.49***	0.53***	0.14
	(0.186)	(0.183)	(0.177)	(0.183)	(0.182)	(0.185)	(0.172)
MICRO	0.76***	0.54***	0.56***	0.72***	0.69***	0.76***	0.34*
	(0.203)	(0.200)	(0.193)	(0.200)	(0.200)	(0.203)	(0.187)
DIST	−0.41***	−0.42***	−0.42***	−0.42***	−0.42***	−0.42***	−0.42***
	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
EPO	−0.60***	−0.60***	−0.60***	−0.60***	−0.59***	−0.60***	−0.60***
	(0.093)	(0.093)	(0.093)	(0.093)	(0.093)	(0.092)	(0.093)
YEAR						0.08*	0.09**
						(0.044)	(0.040)
ρ	0.75***	0.73***	0.71***	0.74***	0.74***	0.75***	0.68***
	(0.017)	(0.018)	(0.019)	(0.018)	(0.018)	(0.017)	(0.021)
n	30 345	30 345	30 345	30 345	30 345	30 345	30 345

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%-significant level, respectively. All estimations include 30 industry dummies (not reported).

Table B1 reports regression results from regressions where EPO patents are included as an observation for each patent (in addition to all the other observations included). 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 is similar to table 3 in all respect except that there are 867 extra observations (with a separate dummy for these) and with no dummy for EPO members. The results are mainly in line with those in the main text. The dummy for EPO is negative and significant. This is in line with expectations, since applications to each individual member country are also included.

Appendix C

Derivation of equation 8

$$V(q)_{ijt}^{\ patent} - V(q)_{ijt}^{\ nopatent} = \int_0^\infty \left(1-e^{-q}\right) Y_{jt} e^{g_j s} e^{-rs} ds - \int_0^\infty \left(1-e^{-q}\right) Y_{jt} e^{g_j s} e^{-(r+k)s} ds$$

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

$$= \left(1-e^{-q}\right) Y_{jt} \left(\frac{1}{r-g_j} - \frac{1}{r+k-g_j}\right) = \left(1-e^{-q}\right) Y_{jt} \left(\frac{k}{\left(r-g_j\right)\left(r+k-g_j\right)}\right) = C_{jt}$$

$$\rightarrow \left(1-e^{-q}\right) = \frac{C_{jt}\left(r-g\ \right)\left(r+k-g_j\right)}{Y_{jt}k}$$

8) $$q_{jt}* = -\ln\left(1 - \frac{C_{jt}\left(r-g_j\right)\left(r+k-g_j\right)}{Y_{jt}k}\right)$$

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 $q_i = q\boldsymbol{\lambda}_i\boldsymbol{\beta}$. For patenting to occur, parameter restrictions are such that $q_i>0$. That is, the quality of patent *i* depends on individual specific characteristics as well as draws from the random variable *Q*. A patent of quality q_i will therefore be patented in country j at time t if q_{ijt} exceeds the right hand side of eq. 8. Accordingly, the threshold value for a patent *i* to be patented in country *j* equals:

9) $$q_{ijt}* = -\left(\frac{1}{\boldsymbol{\lambda}_{\mathbf{i}}\boldsymbol{\beta}}\right)\ln\left(1 - \frac{C_{jt}\left(r-g\right)\left(r+k-g\right)}{Y_{jt}k}\right)$$

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. The condition implies that patent costs relative to GDP are smaller than the difference between effective discounting rates with patenting and without patenting, $C/Y<[1/(r\text{-}g)\text{-}1/(r+k\text{-}g)]$. 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 between zero and infinity and is generally asymmetric. We normalized it to (RCA-1)/(RCA+1) to arrive at a symmetric measure. When a patent was assigned more than one technology class, we use an average.