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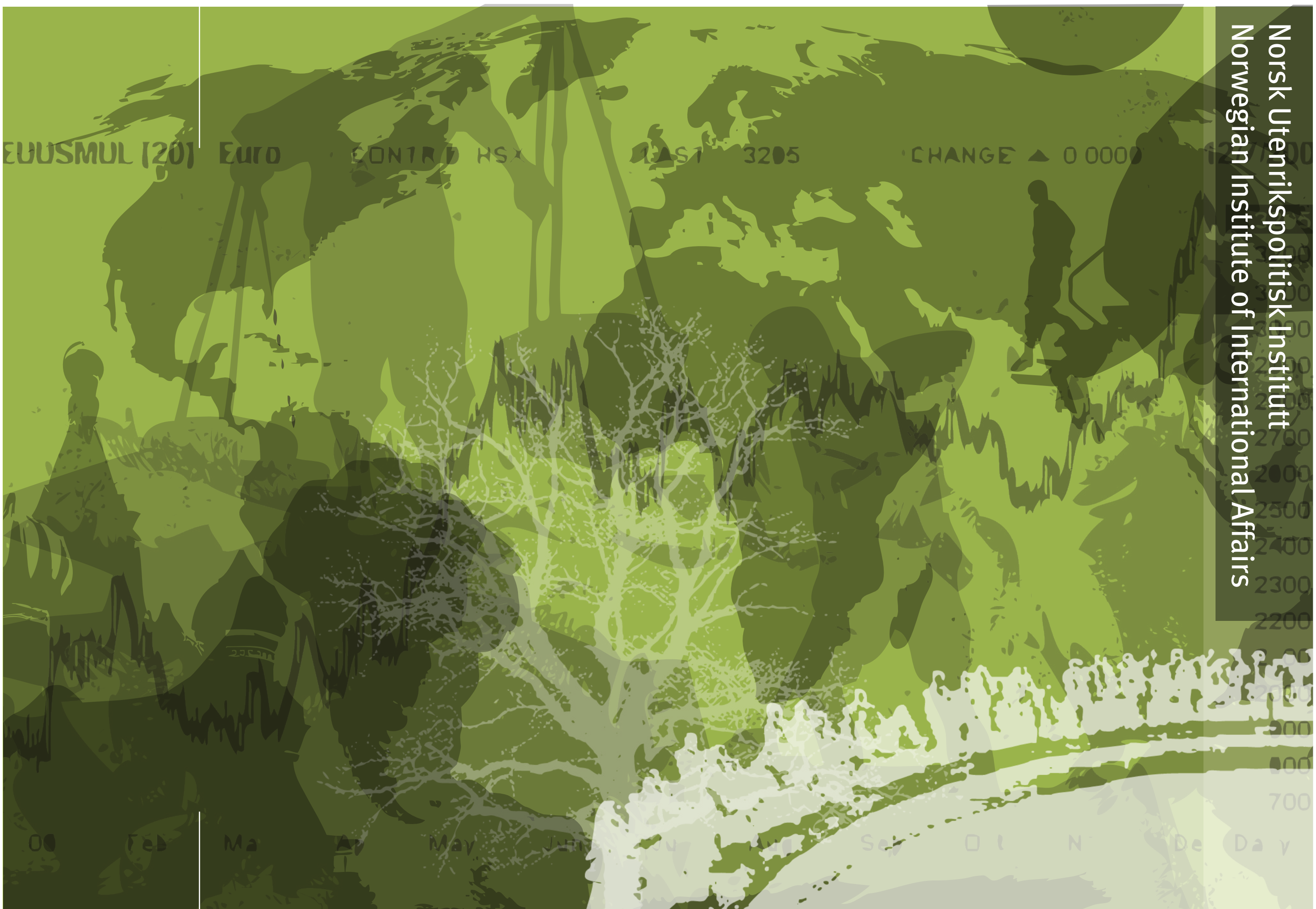

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Abstract
International patenting is increasing in importance. Patents protection is sought in the inventors' homeland but increasingly also in other countries. Globalization, high growth rates in high-tech industries, growing emerging markets and harmonization of patent institutions across countries have stimulated increased international patenting. We use a simple model of international patenting developed by Eaton and Kortum(1996) where the decision to patent in a country depends on country characteristics and the quality of the patented invention. With access to a unique database on Swedish firms' patents and patent behavior we are able to estimate some of these relations and test their validity. Our results indicate that the propensity to apply for international patent protection increases with indicators of the value of the invention and indictors of technological rivalry and market size in the markets where patent applications are submitted.

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1. Introduction

Single patents do not provide protection in all countries and single inventions have to be patented in the countries (or group of countries) where protection is sought. A patent in a specific country protects the inventor from imitators producing in that country and from outside imitators selling there. Therefore protection of intellectual property rights increases with the number of patent equivalents, i.e. parallel patents for a single invention in several regions and countries. Patent protection is costly. Therefore, the decision to seek patent protection in a given country reflects a tradeoff between gains and costs. Generally protection of intellectual property rights is sought only in some countries.

During the last decades, there has been a trend towards strengthening and harmonization of patent institutions across nations and regions. International patenting is increasing in importance and by 2010 more than 40 per cent of all patent applications in world's patent offices are from non-residents. Around 50 percent of the patents granted in the U.S. and Europe are nowadays owned by foreign firms and inventors (Lévêque and Ménière 2004). Still, most patents are patented in one or a few (groups of) countries only.

The purpose of this paper is to analyze the international patenting strategy of small firms and inventors. We have access to a unique database on Swedish small firms' and inventors' patenting behavior. That data base contains information on patenting in Sweden, patent equivalents in other countries and a number of variables reflecting the economic value of the patents, commercialization success and characteristics of the firms and the inventors. The study is explorative in nature. Therefore we first show descriptive statistics on international patenting. Thereafter, the database we use is presented together with some simple statistical tests. In section 4 we present a simple model for international patenting where the probability of patenting an invention from one country in another country is related to characteristics of the invention and indicators of its value and indicators of the market where patent protection is sought, like market size, growth rates and distance from the country of origin (Sweden). We estimate parameters of the model and find that the results are in accordance with the model's predictions.

2. International patenting

International patenting has been facilitated for long. In the early stages of the history of intellectual property rights, discrimination between nationals and foreigners were frequent (see e.g. Scotchmer, 2004). Since the Paris convention was signed in 1883, foreign patent applicants (from other contracting states) were granted the same treatment as national applicants. Thereafter, national patent regulations still differed (and to some extents dramatically) but they rested on national treatment also of foreigners. With the establishment of the TRIPS (Trade Related Intellectual Property Rights) agreement in the WTO from 1995, dramatic steps toward harmonization and standardization of patent regulations have been made. That agreement imposes minimum requirements for patent institutions and patent regulations regulations on member countries.[1] According to Hoekman and Kostecki (1995) "the TRIPS agreement is unique in the WTO context in that it imposes obligations upon governments to pursue specific, similar policies." The TRIPS agreement has resulted in fairly harmonized patent institutions across countries. Patent institutions are still national (or regional, for instance in the case of Europe), but their design is now regulated by the TRIPS agreement and they provide similar and harmonized treatment of national and foreigners.[2]

Some differences of the patent regimes across regions remain. Japan, Europe and the USA have the largest patent institutions internationally (in terms of the number of patents). Traditionally the three systems (although in Europe there were many), differed according to national priorities.[3] In recent years, they have converged considerably. In Eu-

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1 Multilateral co-operation in the field of intellectual property rights was extended after the Paris convention with increasing numbers of member states and a number of new agreements. The agreement on copyrights (the Bern-convention, 1886), the Madrid conventions against false origin (1891), the universal copyright convention (1952), the Rome convention (1961) on protection of neighboring rights and the IPIC treaty (1989) on intellectual property in respect of integrated circuits extend and harmonize IPR internationally. Most of these multilateral treaties on intellectual property rights are administrated by the World Intellectual Property Rights Organization (WIPO) located in Geneva. The TRIPS agreement is administered by the World Trade Organization (WTO). Maskus (2000) provides an overview of intellectual property rights in the world economy. OECD (2004) discuss 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 analysed. For a critical discussion about reforms in the US patent system, see Jaffe and Lerner (2004).

2 There are many exceptions to the general statement above. In particular, exemptions are granted developing countries and countries are free to extend intellectual property rights protections. Developing countries in general resisted introduction of intellectual property rights into the world trade policy systems. See Hoekman and Kostecki (1995) or Maskus (2000) for a discussion.

3 For instance, before 1988 Japanese patents could only include one claim per patent in contrast to Eurpean and U.S. patent which could include multiple claims. Therefore, U.S. and European patents were more open for legal interpretation of their scope However, in

rope and Japan, the “first to file” the patent application will get the patent right. In the U.S., the “first to invent” will get the patent. If a firm files a patent and is granted the patent right, another firm, which have invented first, can regain the right over the patent (Harison 2008). Thus, the validity and novelty of the patent can be challenged in all regions, but the ownership right of the patent application can only be challenged in the U.S.[4] This means that the risk of filing patents is higher in the U.S. than in Europe and Japan.[5]

Another difference is that the European patent system is much more fragmented than the U.S. and Japanese patent systems (van Pottelsberghe 2009 and 2010 and van Pottelsberghe and Francois, 2006). The costs for EPO-patents are considerably higher. After a patent is granted by EPO, the patentee can decide in which country to validate the patent. The patent must be translated to the national language of the countries where the inventor wishes to get a patent right. These translation costs are significant. Renewal fees must be paid in every single EPO member country. There is no unitary European litigation court. Especially high-value patents are subject for litigation. If there are parallel litigations in different European countries, the outcome can be divergent (upholding or invalidating a patent). At the moment, the EU commission has submitted a proposal of a single European patent which only needs to be translated to three languages (English, French and German) and where litigation would be decided at a unitary European court. However, several EU-authorities must approve this proposal.

If a patent is granted by EPO, the national patent offices always have to follow this decision. But if the EPO-patent is rejected or if no EPO-patent is filed, the inventor has always the possibility to get a patent in an individual EPO-member state if the patent is filed directly at the national patent office within the “priority year”.

During the 1970s patenting relative to R&D decreased. This was so for several industrialized countries and for the USA in particular. Both resident and non-resident patent applications *relative* to R&D decreased. For the USA also the absolute number of resident patent applications decreased. In figure 1 these developments for the US are

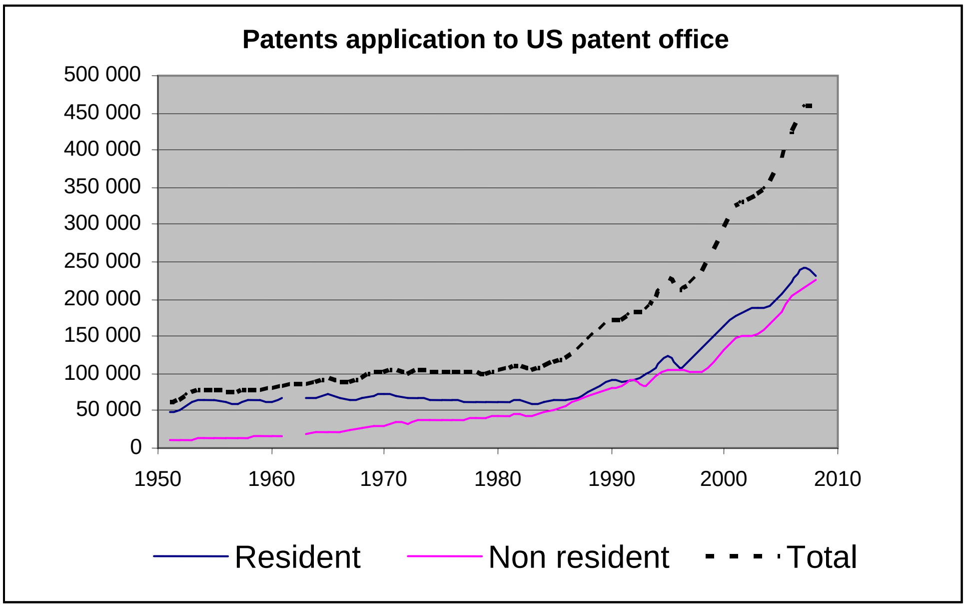
1988 the scope of Japanese patents became broader and several claims could be included in a single patent. Before 2000, U.S. patents were not published until they were granted. Therefore, knowledge disclosure occurred later for U.S. patents than for patents from other countries. In 2000, this rule changed and publication now occurs 18 months after the patent is filed. As a result, knowledge diffusion now starts earlier for U.S. patents and similar to European patents.

4 An exception that the patent ownership can be challenged outside the U.S. is if an employee steals a non-patented invention (theft of firm secrecy) from his firm and then files a patent for the invention. The firm can then claim “better right” and can get the ownership of the patent.

5 A consequence is that the social welfare might be lower in the U.S. as applications are delayed and know-how is not disclosed (Dasqupta 1988).

illustrated. Many economists feared that R&D had entered a phase of decreasing returns and low rates of productivity growth at the same time increased pessimism.

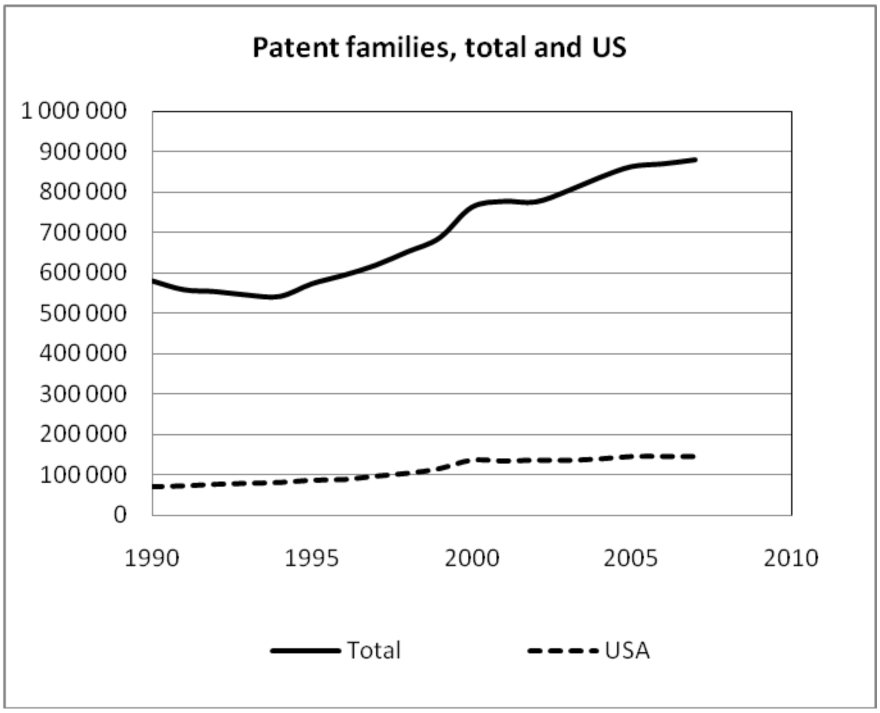
Figure 1



Source: WIPO

From figure 1 it is obvious that this pessimism, at least when primitively read off from data for patent applications, was not well founded. From the mid-1980s onwards patenting surged. Both national and non-resident patent applications increased. For the world economy, the number of patent families (i.e. the number of patented inventions, inclusive of their patent equivalents) has increased. This is illustrated in figure 2.

Figure 2



Source: WIPO

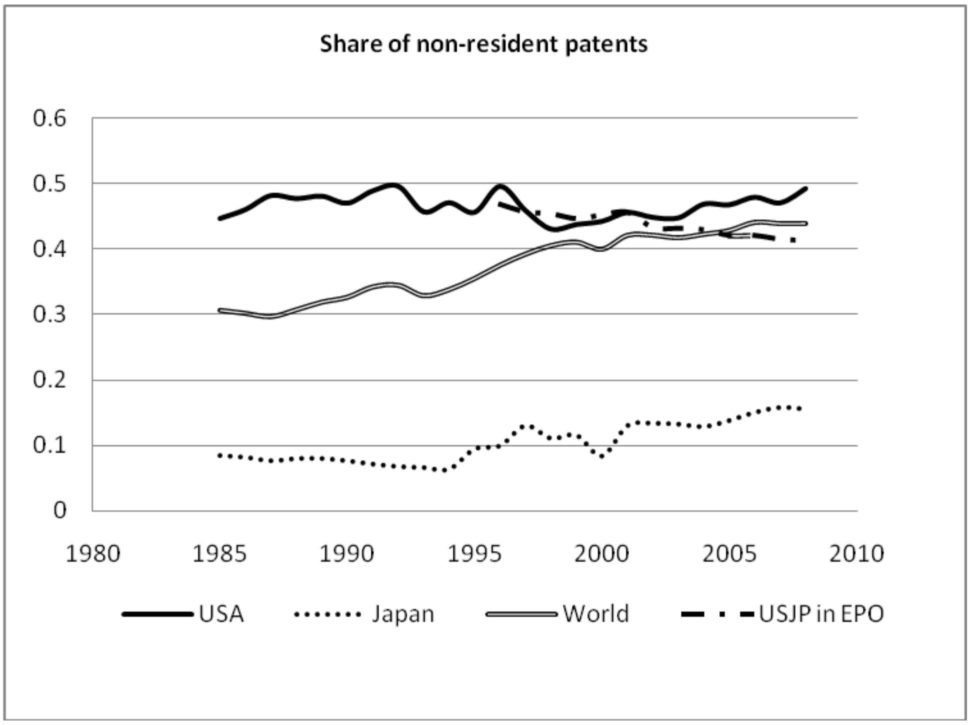
Figure 2 shows the total number of patent families for all countries and for those originating in the USA. The figure demonstrates a global and strong increase in patenting since 1994 onwards.

Figure 1 illustrated that patent applications from non-residents in the US has increased in parallel with domestic patent applications. This is also the case for non-resident patent applications in other countries. Figure 3 shows developments for all countries, for the USA and Japan and for US and Japanese patents in EPO.[6]

These figures indicate that non-resident patenting has kept a stable share of total patenting for the major economies while international patenting is on increase for the world economy in total. This seems to have occurred independently of the TRIPS agreement in the WTO. In figure 3 there is no break in aggregate time series for global international patenting in 1995, when the TRIPS agreement came into force.

6 Figures are different for the European Patent Office since the member countries change over time. Therefore, internationalization is demonstrated most clearly with the use of large outside countries.

Figure 3



Source: WIPO

There was a debate among economists on decreasing trends in patenting in the 1970s and 1980s.[7] Zvi Griliches (1989) pointed at institutional weaknesses in the patent system to explain the falling trend. Subsequent institutional reforms (both in the US, in Europe, in other countries and multilaterally) may lend support to Griliches' view. Samuel Kortum (1993), on the other side, has argued that developments in the number of patent applications (both from residents and non residents) can be explained by economic developments. He has argued that accelerated economic integration from the 1990s onwards has increased market sizes for new technologies and therefore profitability from innovation. The effects of patent institutional reform and the TRIPS agreement from 1995 onwards are still up for debate.

Our discussion above indicates that international patenting is of great importance as compared to national patenting. International patenting has been the subject for a few analyses. A classic reference is Evenson (1984). That contribution is a descriptive discussion of trends in international patenting (based on rather limited data). Evenson reaches two main conclusions. The first is that his (by now) historical data show

7 The pros and cons of using patent statistics as an economic indicator are well known. (see e.g. Griliches, 1990). All inventions do not result in patents and the propensity to patent vary between technologies, industries and even countries. The access to easily read and clear microdata is the main advantage of using patentdata rather than data on innovations.

comparative advantage patterns in invention similar to patterns observed in countries' production. Thus knowledge production is concentrated in economies with comparative advantages in high tech industries. Second, Evenson provides support for the pessimistic view (at that time) that the number of inventions per scientists was on a declining trend in the early 1980s. More recent contributions are Putnam (1996) and Lanjouw et al. (1996). Also see Harhoff *et al.* (2009).

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, 1082 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 inventors of the patents.[9] 867 (out of 1082) inventors filled in and returned the questionnaire, i.e., the response rate was 80 percent. The falling off is not systematic with respect to IPC-classes or geographical regions.[10] The response rate is satisfactorily high, given that such a database has seldom been collected before and that inventors or applying firms normally consider information about inventions and patents confidential.

The questionnaire asked the inventors about the work place where the invention was created, if and when the invention had been commercialized, which kind of commercialization mode was chosen, the profitability of the commercialization, and some more information. The data set was later complemented with data on patent renewal, international patents and forward citations from the Espacenet (2010) website.

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

8 In 1998, 2760 patents were granted in Sweden. 776 of these were granted to foreign firms, 902 to large Swedish firms with more than 1000 employees, and 1082 to Swedish individuals or firms with less than 1000 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 fill-in questionnaires about patents. These firms are almost always large multinationals firms. The sample selection in our data is not a problem however, as long as the conclusions are drawn for small firms and individuals located in Sweden.

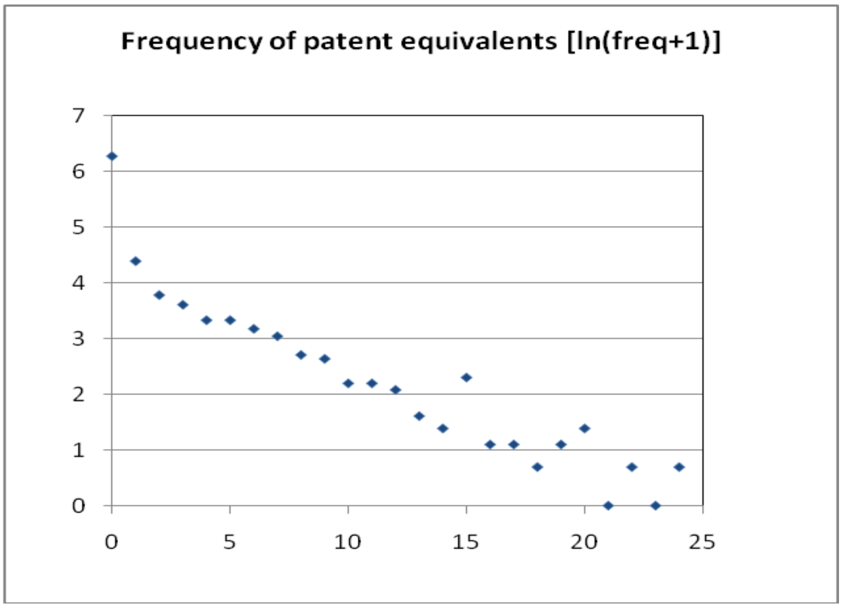
9 Each patent always has at least one inventor and often an applying firm as well. The inventors or the applying firm can be the owner of the patent, but the inventors can also own the patent indirectly, via the applying firm. Sometimes, the inventors are employed in the applying firm, which owns the patent. If the patent had more than one inventor, the questionnaire was sent to only one of the inventors.

10 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.

every year.[11] The option for further renewal is acquired by renewing the patent at each mandatory date. In our dataset an indicator variable (ALIVE) express whether the patent has been renewed until the time the data were collected or whether it had lapsed.

The 867 patents in the database has together 1 733 patent equivalents in other countries, i.e. almost exactly two equivalents per patent. But only 335 (39 %) out of the 867 patents in the data set have any patent equivalents at all. This means that given that a Swedish patent has any equivalents, the average number of equivalents per patent is 5.2. The frequency distribution (log scale) of patent equivalents (plus one – to account for zeros) is graphed in figure 4. It is seen that the distribution is highly skewed with a preponderance of zeros and small numbers. The maximum number of equivalents for a given patent is 24. These numbers include EPO as one observation. Thus, the maximum number of equivalents in individual countries is 23.

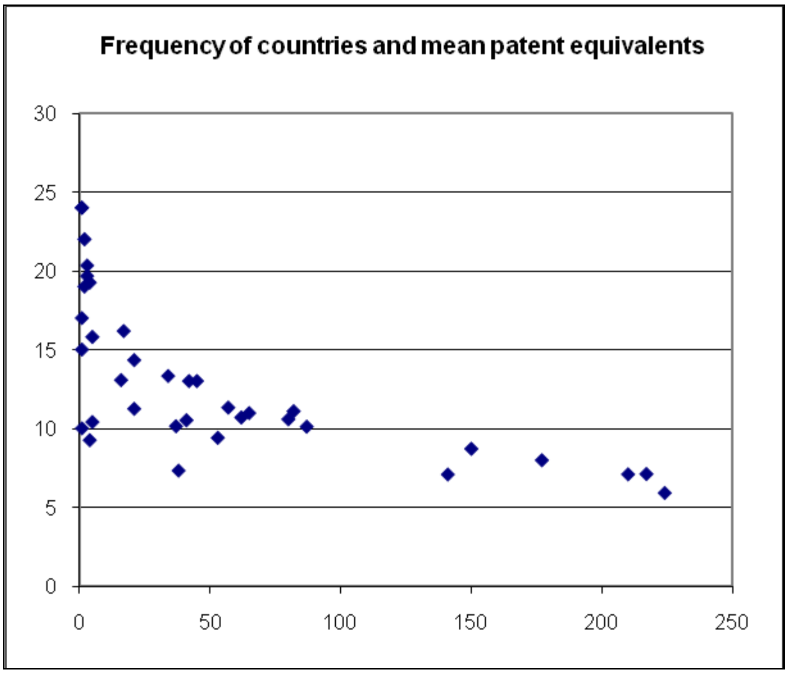
Figure 4



[11] A patent can only expire at a fixed date every year, on the anniversary of the original application date. In 1999, the size of the renewal fees was increasing annually, ranging from 200 SEK in the first year to 4 300 SEK in the last year, adding up to total of about 35 000 SEK over 20 years (One EUR is approximately 8 SEK). The Swedish renewal fees are modest compared to those for EPO and American patents (van Pottelsberghe and Francois (2006). According to Van Pottelsberghe and Francois (2006), the total cost for a patent which is renewed for 20 years is EUR 120 000 (40 000) in 13 (3) EPO member states, EUR 14 500 in the U.S. and EUR 17 300 in Japan. These costs include procedural costs (official costs up to the grant date) and external services that the inventor/firm needs when filing the patent. EPO patents are much more expensive due to high translation costs – the granted patent must be translated and validated in each targeted national patent office. The other reason why EPO patents are more expensive is higher annual renewal fees (which vary with the duration of the protection). The authors show that renewal fees for 20 years in the EPO system are EUR 89 000 (22 000) in 13 (3) member states, whereas this cost is considerably lower in the U.S. and Japan. However, the renewal fees in single European countries like Sweden are of a modest amount.

In total there are patent equivalents in 36 countries (including EPO). As will become clear from the analysis in section 5 below, patent equivalents are not distributed randomly across those countries. Figure 5 shows the correlation between the average number of patent equivalents (horizontal axis) and the occurrence in the different countries. For instance, patent equivalents occur 224 times in the USA. The mean number of patent equivalents for an invention with a patent equivalent in the USA 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). The graph displays a negative correlation. This means that those countries that are seldom chosen for patent applications occur mostly when also other countries are chosen.

Figure 5



224 Swedish patents in the data set had equivalents in the U.S. and 217 had an EPO-patent. The EPO-patent must then be filed in individual countries. The EPO-patents resulted in 1106 individual patents in the EPO-member countries, i.e. on average 5.1 individual patents per EPO-patent. The EPO-patents are filed most frequently in Germany, Great Britain and France – the large EPO-countries. In the third main area, Japan, the Swedish patents had 141 equivalents.

The database contains information about firm size and type of the patentee. This information was categorized into four main types, medium sized firms (101-1000 employees), small firms (11-100), micro firms (2-10 employees) and individual inventors (no employees). The database also contains information about renewal of patents (measured by ALIVE, as mentioned).

In addition, we use information about forward patent citations. Patent documents contain references to existing patents. These references serve to delimit the scope of patent protection. Often it is assumed that these references indicate the type of knowledge that the citing patent extends or build on. There literature on patent citations show that such citations are indicators of patents' private and social value (see e.g. Jaffe and Trajtenberg, 2002). Generally this literature suggests that patents that are frequently cited by subsequent patents have a higher private and social value than other patents. Maurseth (2005) suggests that forward citations within narrowly defined technology classes may indicate new rival knowledge vis-à-vis the cited patent. Forward citations across technology classes, on the other hand, may indicate that the cited patent was a scientific or technologically breakthrough, and therefore that the cited patent may both have higher social and private values than other patents.

But whether or not patented inventions are commercialized and brought to market differ. Many patents fail in the commercialization process while some becomes successful. Some patents may not be commercialized however, but are kept alive as a buffer against rivals' potential market entries. Some inventions may be commercialized without being patented.[12]

Tables 1, 2, 3 and 4 show partial relationships between the number of patent equivalents and firm types, patent renewal, the number of patent citations and the commercialization decision, respectively.

The international patenting strategy across firm sizes is shown in Table 1. In the sample, 116 patents is owned by medium-sized firms (101-1000 employees), 201 by small firms (11-100), 142 by micro companies (2-10 employees) and 408 by individual inventors. Firms have considerably more patent equivalents than individual inventors. This is expected, since international patenting is costly. For example, 54 % of the medium-sized firms in the sample had an equivalent in at least one of the three main areas (USA, EPO and Japan), whereas only 27 % of the individual inventors had chosen such a strategy. The differences in patent equivalents across firm groups are mostly significant using chi-square tests, except for the case of patent equivalents in all three main areas.

[12] Non-patented inventions are obviously not covered by our database, however.

Table 1. International patenting across firm groups. No. of patents and percent.

Firm groups	Medium-sized firms (101-1000 employees)	Small firms (11-100 employees)	Micro companies (2-10 employees)	Individual inventors (no employees)	All patents	Chi-square test
No. of patents	116	201	142	408	867	------
Patents in 3 main areas	17 (15 %)	22 (11 %)	12 (8 %)	28 (7 %)	79 (9 %)	7.7 *
Patents in at least 2 main areas	30 (26 %)	45 (22 %)	41 (29 %)	76 (19 %)	192 (22 %)	9.7 **
Patents in at least 1 main area	63 (54 %)	76 (38 %)	62 (44 %)	110 (27 %)	311 (36 %)	35.3 ***
Any international patent	66 (57 %)	87 (43 %)	66 (46 %)	116 (28 %)	335 (39 %)	39.7 ***
Average No. of patents	2.54	2.10	2.44	1.64	2.00	------

Note: The three main areas are EPO, USA and Japan. ***, ** and * indicate significance at the 1, 5 and 10 % level, respectively.

Table 2. International patents and survival of patents. No. of patents and percent.

	Renewed in 2004		All patents	Chi-square test
	Yes	No		
No. of patents	482	385	867	------
Patents in 3 main areas	68 (14 %)	11 (3 %)	79 (9 %)	32.7 ***
Patents in at least 2 areas	159 (33 %)	33 (9 %)	192 (22 %)	74.0 ***
Patents in at least 1 area	232 (48 %)	79 (21 %)	311 (36 %)	70.9 ***
EPO-patent	185 (38 %)	32 (8 %)	217 (25 %)	103.1 ***
US-patent	167 (35 %)	57 (15 %)	224 (26 %)	44.0 ***
Japan-patent	107 (22 %)	34 (9 %)	141 (16 %)	28.1 ***
Average No. of countries	3.09	0.63	2.00	------

Note: The three main areas are EPO, USA and Japan. ***, ** and * indicate significance at the 1, 5 and 10 % level, respectively.

In Table 2, international patents are compared to the renewal of patents. Here, we expect a positive relationship, since both renewal and international patenting should be related to the private value of a patent. Patent renewal behavior has been investigated in many articles and patent renewal has often been used to infer about the private value (distributions) of patents.[13] Patents which were still alive in 2004 had considerably more often equivalents than expired ones. For example 33 % of the patents still alive in 2004 had equivalents in at least two of the three main areas, but only 9 % of the expired patents. The chi-square tests of independence between groups are never lower than 28 which is very high, since the threshold value for 1 percent significance is 6.3

Table 3. International patents and forward citations. No. of patents and percent.

	Forward citations		All patents	Chi-square test
	Yes	No		
No. of patents	350	517	867	------
Patents in 3 main areas	73 (21 %)	6 (1 %)	79 (9 %)	97.8 ***
Patents in at least 2 areas	159 (45 %)	33 (6 %)	192 (22 %)	184.6 ***
Patents in at least 1 area	252 (72 %)	63 (12 %)	311 (36 %)	493.4 ***
Patents in none of the three main areas	98 (28 %)	454 (88 %)	556 (74 %)	
EPO-patent	181 (52 %)	36 (15 %)	217 (25 %)	222.7 ***
US-patent	185 (53 %)	39 (7 %)	224 (26 %)	223.6 ***
Japan-patent	114 (33 %)	27 (5 %)	141 (16 %)	114.6 ***
Average No. of countries	4.00	0.64	2.00	------

Note: The three main areas are EPO, USA and Japan. ***, ** and * indicate significance at the 1, 5 and 10 % level, respectively.

When relating international patenting to forward citations in Table 3, the positive relationship is even stronger. Patents with forward citations had 4.0 patent equivalents on average compared to 0.64 for patents without equivalents. 72 % of the cited patents had equivalents in at least 1 main area, but only 12 % of the non-cited ones, etc. Or from

[13] See e.g. Pakes and Schankerman (1984), Pakes (1986), Pakes and Simpson (1989), Schankerman (1998) and Schankerman and Pakes (1986).

another point of view, 81 % (252 out of 311) of the patents with equivalents in at least 1 main area are cited, whereas only 18 % (98 out of 556) of the patents with no equivalents any main area are cited. Forward citations are considered as a measure on the social value of patents. One reason for this is that patents that are cited in subsequent patents' patent documents 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). Thus, a positive correlation between the number of patent equivalents and the number of forward citations is as expected. 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. The explanation for the high correlation between the number patent citations and the number of equivalents could be that when a Swedish patent has equivalents in EPO, Japan or the U.S., the patent is much more visible for patent examiners. This will increase the probability that the patent is cited even if the patent citations do not signal higher values of the cited patent.

Table 4. International patents and commercialization. No. of patents and percent.

	Commercialization		All patents	Chi-square
	Yes	No		test
No. of patents	526	341	867	------
Patents in 3 main areas	60 (11 %)	19 (6 %)	79 (9 %)	8.5 ***
Patents in at least 2 areas	146 (28 %)	46 (13 %)	192 (22 %)	24.4 ***
Patents in at least 1 area	233 (48 %)	78 (23 %)	311 (36 %)	41.3 ***
EPO-patent	165 (44 %)	52 (15 %)	217 (25 %)	28.6 ***
US-patent	168 (32 %)	56 (16 %)	224 (26 %)	26.0 ***
Japan-patent	106 (20 %)	35 (10 %)	141 (16 %)	14.9 ***
Average No. of countries	2.62	1.04	2.00	------

Note: The three main areas are EPO, USA and Japan. ***, ** and * indicate significance at the 1, 5 and 10 % level, respectively.

In Table 4, international patenting is related to commercialization. Here, we also expect a positive relationship, since more valuable patents should both have more equivalents and be commercialized with a higher probability. The descriptive statistics give support to this view. The chi-square tests strongly rejects that there is independence between commercialization and equivalents. Commercialized patents have more frequently patent equivalents than non-commercialized ones. For example, 48 and 28 % of commercialized patents have equivalents in at least 1 or 2 main areas, whereas corresponding figures for non-commercialized patents are 23 and 13 %.

4. A model set up for to investigate international patenting

The modeling set up presented below is the one developed by Eaton and Kortum (1996). Their model is a full fledged endogenous international growth model in which international patenting plays important roles. 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 the each invention and a probabilistic applicable parameter. 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 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 to patent internationally depend on market size, protection of intellectual property rights 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 microdata and this allows us to formulate patent owners' choice about where to patent.

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

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

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 innovation. Innovations improve the quality of an intermediate with a specific percentage amount, which is defined as the size of the invention. The size of an invention is a random variable Q drawn from an exponential distribution.[14] When an innovation is adopted to one intermediate Z_v, the quality raises to Z'_v defined as:

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

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 innovated intermediate charge the highest possible price at which production without that innovated 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 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 next to highest quality. This firm's price optimal equals w after the leader has entered the market. The produced quantity for a firm producing the intermediate v depends then on the demand function derived from eq. 1. This demand function is given by eq. 3.

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

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

Profits from an innovation of size q is therefore equal to:

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

Eq. 4 relates profitability of patenting to market size. This proves to be an important empirical regularity.[15]

A patent reduces the probability that the innovation will be imitated in any period during the patents lifetime from k to zero. For simplicity we assume that patents last forever.[16]

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14 The average step of an invention can be parameterised as 1/θ.

15 For similar formulations of the above relationships, see Eaton and Kortum (1996) or Grossman and Helpman (1991a or 1991b, ch. 4).

The discounted values of an unpatented and patented innovation of quality q in country j originating in country i at time t are therefore:

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

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

Above, r denotes the discount rate and g the growth rate in the economy. The value of patenting is the difference $V(q)_{ijt}^{patent}$-$V(q)_{ijt}^{nopatent}$. 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

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

determines the threshold quality level q* such that innovations of higher quality are patented while those with lower qualities are not.[17]

The threshold q* is given in eq. 8. The derivation of it is presented in the appendix.

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

It is seen from eq. 8 that the threshold value for q 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. The following results are easily derived:

16 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.

17 Note that the cost function, C, has subscripts jt. This indicates the country in which patent protection is applied for and the time when patent protection is applied for. It does not indicate in which country the patent originate however. This reflects the requirement in most international patent treatments of *national treatment*, i.e. that foreign applicants shall treated similar to national applications.

Lemma 1.

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

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

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

These three results have the following characteristics:
The first simply means that the higher the patenting costs, the higher is the threshold value for the quality of an innovation to be patented. Therefore, the higher the patenting costs in a country, the lower is the probability that an invention will be patented in that country. The second result means that the larger is the GDP in a country the lower is the threshold value for the quality of an innovation to be patented. Therefore, the probability that an invention will be patented will be increasing in the market size of a given country. The third result is similar for growth in total GDP.

Generally, the quality of patented inventions has unknown distributions. If it is, for instance log normal, the log of returns will be normal. Many other distributions will be possible to analyze. A rough approximation will be to analyze the binary choice (to patent or not) as

$$9) \qquad PQ_{jt} = \begin{cases} 1 \text{ if } q_{jt} \geq q_{jt}^{*} \\ 0 \text{ otherwise} \end{cases}$$

Above, PQ_{jt} denotes whether a patent of quality q is patented in country j or not. Note that the threshold value of the quality of an invention to be patentable is country specific. It depends on characteristics in the country where patent protection is sought. If we assume that a patent's quality can be written as observable patent specific characteristics multiplied with a basic random variable so that for a patent k, $q_k=qh(x_k)$, the probability that the owner of an invention k seeks protection in a country j can be written as

$$10) \qquad P(PQ_{jk} = 1) = f(\alpha_k \mathbf{Q} + \beta_j \mathbf{T})$$

In eq. 10, **T** denotes a vector of characteristics of the country in which patent protection is sought while **Q** denotes a vector of characteristics of the patented invention.

5. Econometric analysis

Our empirical strategy is to run probit regressions on variants of the above regressions. In our dataset with 867 observations we have dummy variables for whether a patent is applied for in any of the 36 countries where patents are applied for. On the basis of this, we create an expanded dataset consisting of 867*36 (=31212) observations. That is, the observational unit is constructed to be the choice to apply for patent protection for patent *k* in country *j*. We collect country specific data from the World Development Indicators (World Bank, 2011) . We lack data for Taiwan (for which there is one patent application). The dataset used in the regressions therefore consists of 35*867=30 345 observations.

The vector of country specific variables includes:

- Total GDP. This is predicted by the above model. Total GDP reflects market size in the country in which protection is sought. We use GDP in 2000.
- Growth in GDP in the period from 1995 to 2000.
- Patent costs.

It follows from the theoretical model (and intuition) that patent costs should be included as explanatory variable. This variable is not available for all countries. One reason for this 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. This also adds costs which may be diverse. Then 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 member countries in the European Patent Organization, patent protection can be sought in many countries via the European Patent Office. If so, the patent needs to be validated and (if granted) 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. There is no patent cost index for all countries. We have therefore chosen to use the results from the survey by Helfgott (1993) where patent costs for a number of countries are presented. There are three problems with using this database. The first is that the survey is old. The patents covered by our database were granted in 1998. The patent equivalents that we are interested in were therefore applied for by the late 1990s. The costs reported in Helfgott are therefore too low as compared to the costs faced by the applicants. Furthermore, we do not know whether they changed proportionally to each other or not. The second problem is that patent costs via EPO are reported. These should be added validation costs in individual countries to reflect the costs faced by the Swedish firms when applying for patent equivalents in other EPO member countries. We do not have access to these validation costs. We choose to include EPO as a single observation in versions of our regressions and leave EPO out in others. The third problem with the use of the available cost data is that the overlap between countries in the Swedish patent database and those in Helfgott's is limited. We have cost data for 23 of the 36 countries for which we have Swedish patent equivalents data (including EPO).[18] We report separately results when cost data are included and when they were not included.

The variables GDP, growth in GDP and patent costs follow directly from our modeling exercise. In addition we include in several specifications:

- GDP per capita. It may be the case that a country's GDP per capita reflects the technological level of this country and therefore a higher probability of being imitated. The a priori assumption would be a positive effect.
- Distance between Sweden and the country in which patent protection is sought. This variable should be included for two reasons. First, trade is known to depend negatively with 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 in question. The inventor may have to travel there. Languages are different. Culture is different.
- R&D intensity (as percent of GDP) reflects increased probability of being imitated.

The vector or patent specific variable vector includes variables from the database. These are:

- Firm type. We have reasons to expect higher international patent propensities independently from patent quality from large firms due to credit constraints. This hypothesis follows from the results presented in table 1. The firm types are included in the regressions as dummy variables.

[18] In the appendix we report the countries that are covered in the cost database and in the database for patent equivalents.

- Commercialization. The database contains information about whether the invention was commercialized. It is natural to assume that commercialized patents will have a higher value so that they will be patented in more countries.
- Patent survival is a clear and direct indicator of the quality of a patented invention. We include a dummy variable for whether the patent was still alive in 2004 and also the year for which it was first applied for.
- Forward citations. For our analysis patent citations are assumed to reflect exogenous characteristics of the patent. Many studies indicate that forward patent citations reflect underlying private and social values of the patent. Higher private value would imply lower q and higher probability of patenting the invention in any market. Higher social values could imply stronger technological rivalry against the patented invention and therefore higher values of patenting. In this connection, the relationship between forward patent citations and international patenting should a priori be expected to be strong. The value of patenting become stronger the higher the probability of being imitated is. Forward citations may reflect higher probability of imitation. In line with Maurseth (2005) we discriminate between citations within and between technologies in order to trace possible different effects. We exclude self citations.

One of our main hypotheses is that valuable patents will be patented to a higher degree than less valuable patents. Our empirical strategy is therefore to include as explanatory indicators of the value of patented inventions. The variables listed above are all candidates for being such indicators. They are therefore included in versions of the regressions, reported in table 6.

However, we have reasons to believe that our data is characterized by endogeneity problems. If a patent proves valuable, it will probably both have higher probabilities of commercialization, it will be renewed for longer periods, receive more patent citations *and* have a higher probability of getting patent equivalents in any countries. It is not clear at the outset that causality runs from any of our right-hand value indicators to patent equivalents. In principle it might be that causation runs in both directions or from our dependent variable towards to independent variable. We do not solve these endogeneity variables here. Rather, in table 5 therefore, we report results including the country specific variables *and* successively variables that reflect patents' value with increasing problems (in our view) with endogeneity.

Table 5. Probit regression results on patent equivalent.

Variable						
lGDP	0.33	0.33	0.34	0.35	0.37	0.36
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
lGDPcap	0.25	0.25	0.26	0.26	0.28	0.27
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
ldistance	-0.19	-0.19	-0.19	-0.19	-0.21	-0.21
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
Growth	4.19	4.21	4.26	4.35	4.57	4.54
	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
L(RD/GDP)	0.09	0.09	0.10	0.11	0.11	0.11
	(.006)	(.008)	(.006)	(.003)	(.003)	(.003)
101-1000 wo		0.24	0.19	0.01	-0.03	0.04
		(.000)	(.000)	(.753)	(.354)	(.268)
11-100 wo		0.14	0.07	-0.03	-0.05	-0.03
		(.000)	(.028)	(.355)	(.183)	(.431)
2-10 wo		0.24	0.15	0.08	0.04	0.06
		(.000)	(.000)	(.041)	(.333)	(.088)
Comm.			0.51	0.40	0.37	0.38
			(.000)	(.000)	(.000)	(.000)
Still alive				0.84	0.81	0.82
				(.000)	(.000)	(.000)
Cites - within					0.19	0.20
					(.000)	(.000)
Cites - betw					0.48	0.49
					(.000)	(.013)
Applic. date						0.58
						(.000)
N	30345	30345	30345	30345	30345	30345
Pseudo-R^2	.17	.17	.19	.20	.25	.28

Note: Dependent variable is the existence of patent equivalent of patent k in country j. Heteroscedasticity-consistent p-values in parentheses. For firm groups, firms without employees are reference group

The first column report results when country specific variables only are included. That regressions lends support to our main hypothesis from the modeling exercise above. Market size (log of total GDP), welfare (log of GDP per capita in PPP), (log of) distance from Sweden and growth rates in total GDP all correlate positively with the probability of triggering a patent equivalent. So does (log of) R&D intensity.

Market size (log of total GDP) has positive and highly significant impacts on the probability of attracting patent equivalents. This means that large countries are the most likely to receive patent applications from Sweden. The same result holds for rich countries. This is harder to interpret, but since rich countries are the most technologically advanced we interpret this result as two sided: First, technologically advanced countries may be those where probabilities of imitation are the largest. Thus intellectual property rights may be more profitable. Second, rich countries may have larger markets. Thus, the need for intellectual property rights may be larger (since it may be more profitable to export to rich countries). The growth variable is growth in GDP per capita in the period from 1995 to 2000. We use this period since we expect it to reflect *expected growth* in the relevant market. Also this variable has a positive and significant sign in line with out expectations.

Geographical distance retards patent equivalents. The distance variable is geographical distance in kilometers based on the latitude and longitude of the countries' capitals.[19] Our interpretation is again two sided: First, distance is known to retard exports. Thus distant countries are, *ceteris paribus*¸ less important markets. Consequently, the need for intellectual property rights is less since the innovation may not be marketed in such markets. Second, it may be that distance in some way reflects the costs of dealing with a country. If patent costs also include cultural and linguistic costs, the negative and significant result may also reflect higher patenting costs. In future research we intend to include also formal patent costs as explanatory variable. This will qualify our interpretation also of the estimated coefficient of the distance variable.

Note that the above 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). Harhoff and his co-authors find similar results for the aggregate number of patent equivalents between these countries. They depend positively on market size, negatively on distance and negatively on costs (see below).

R&D intensity in the country where patent protection is sought has a positive and (mostly) significant sign. We expect R&D intensity to indicate higher imitation probabilities and therefore higher profitability of patenting. The results are in accordance with this expectation.

Column two, three, four, five, six and seven, successively introduce patent specific variables. The second column reports results from inclusion of indicators of firm size. Firm size (in terms of employment) influences positively and significantly on the probability of equivalent patents. Firms without employment (and independent innovators) constitute the reference group, so other types of firms have higher proba-

[19] EPO is located (with its headquarter and in our data) in Munich. We report results from regressions both when patent applications to EPO is included as one observation and for regressions where EPO membership is included as a country specific dummy variable.

bility of international patenting than these. Note that this effect is not increasing linearly with the number of employees. It is largest for the largest and for the smallest firms. In the third column a dummy for commercialization in Sweden is included. It is seen that also this variables correlates with the probability of international patenting. The result is as expected and it is highly significant. The endogeneity issue might be present however: It might be that commercialization (and therefore the existence of patent equivalents) contributes to national success in Sweden. We doubt that this effects is large and important. The next column is for additional inclusion of a dummy variable for whether the patent was renewed until the survey was undertaken (2003-04). Whether the patent had lapsed or not does also seem to be of importance. Patents still alive have higher tendencies to be applied for in other countries.

Application date (year) also matters. The positive coefficient indicates that younger patents have more equivalents than older (application year ranges from 1985 to 1998). So does whether the patent was commercialized in Sweden. Also the number of forward citations matter. Note that citations both within and between technology classes matter. These technology classes are defined according to whether the cited and the citing patent belong to the same narrowly defined technology class (IPC number). In Maurseth (2005) it was found that patents that were cited by citing patents within the same technology class lapsed earlier. Such citations were therefore interpreted as rival patents that potentially may make the patent obsolete. In our context such rivalry should increase the profitability of patenting. The positive and significant coefficient is in line with this interpretation. Inter technology class citations may indicate high economic values of a patent. Such a patent may mark a scientific breakthrough and open up opportunities for further research. The positive and significant coefficient is in line with this interpretation. For our interpretations of the effect of citations one should note the above warning that there may also be spurious correlations and possibly endogeneity problems. In future research we intend to go deeper into this issue.

Sweden is a member country in EPO. Furthermore, it is not clear that EPO can be included as one observation as we have done in table 5. In table 6 therefore, we report some results when EPO is taken out of the sample and when the other countries are characterized with the dummy variables EPO (EPO=0 for non-members and EPO=1 for members). In table 6 we also report results from regressions where patent costs are included.

The EPO dummy variable is positive and significant. This is reported in the first column in table 6. To some extent this indicates some success of the EPO. The Swedish patentees apply more often for patent protection in other EPO countries than in other countries. Such patents are automatically granted in other EPO countries when also granted in Sweden if the patentee pays validation fees and live up to prerequisites for patenting in the other EPO countries. This finding gives support to the view that design of patent institutions matter. Interestingly, the other variables (mostly) keep their sign and significance when the EPO dummy variable is included.

In the second and the third column we also introduce costs in the regression. Note that this reduces the number of observations considerably since we have access to patent costs for some countries only. Therefore, the coefficients for the other variables are not directly comparable when costs are included. Still, all keep their sign and most keep their significance when costs are included. The sign of the cost variables is (as expected) negative but it is not significant. Similar results were found by Harhoff *et al.* (2009). But in the third column we included both the EPO dummy variable and the cost variable. In this case the cost variable is not significant any longer, but the sign remains.

Our results for patent costs are fairly in line with our expectations even if the data are too old, too few and not properly take into account the case of EPO. Therefore, the results lend support to our prime priors about the impact of patent costs.

Table 6. Probit regression results on patent equivalent.

Variable			
lGDP	0.40 (.000)	0.43 (.000)	0.41 (.000)
lGDPcap	0.20 (.000)	0.33 (.000)	0.42 (.000)
ldistance	-0.18 (.000)	-0.28 (.000)	-0.13 (.000)
Growth	3.66 (.001)	0.49 (.816)	1.42 (.484)
L(RD/GDP)	0.83 (.040)	0.02 (.737)	0.13 (.011)
EPO	0.30 (.000)		0.38 (.000)
Costs		-15 (.120)	-0.037 (.710)
101-1000 wo	0.41 (.301)	0.04 (.370)	0.042 (.351)
11-100 wo	-0.05 (.183)	-0.03 (.515)	-0.03 (.529)
2-10 wo	-0.04 (.307)	0.04 (.367)	0.04 (.351)
Comm.	0.38 (.000)	0.36 (.000)	0.36 (.000)
Still alive	0.80 (.000)	0.80 (.000)	0.81 (.000)
Cites - within	0.18 (.002)	0.21 (.000)	0.22 (.000)
Cites - betw	0.46 (.002)	0.47 (.000)	0.47 (.000)
N	29478	17340	17340
Pseudo-R^2	.27	.23	.24

Note: Dependent variable is the existence of patent equivalent of patent k in country j. Heteroscedasticity-consistent p-values in parentheses. For firm groups, firms without employees are reference group. Note that the cost coefficient is multiplied with 1000. It was originally reported in USD.

The dataset consists of the patent dimension and the country dimension. Therefore the more than 30 000 observations are not independent. In principle the structure of the data is a panel. The cross section dimension is for the patents. The other dimension is for countries. In table 7 we reproduce the results from table 6 from a panel data regression. The results are fairly similar to those reported above. One difference is that patent costs are now negative and significant when the EPO dummy variable is left out.

Table 7. Panel probit regression results on patent equivalent.

Variable			
lGDP	0.70 (.000)	0.70 (.000)	0.68 (.000)
lGDPcap	0.34 (.000)	0.52 (.000)	0.66 (.000)
ldistance	-0.30 (.000)	-0.45 (.000)	-0.24 (.000)
Growth	5.83 (.001)	1.93 (.489)	3.39 (.223)
L(RD/GDP)	0.10 (.040)	0.04 (.494)	0.19 (.003)
EPO	0.41 (.000)		0.54 (.000)
Costs		-0.26 (.046)	-0.116 (.380)
101-1000 wo	0.23 (.181)	0.23 (.200)	0.23 (.201)
11-100 wo	0.11 (.500)	0.108 (.499)	0.11 (.493)
2-10 wo	0.23 (.205)	0.29 (.122)	0.29 (.120)
Comm.	0.69 (.000)	0.68 (.000)	0.69 (.000)
Still alive	1.19 (.000)	1.19 (.000)	1.20 (.000)
Cites - within	0.52 (.000)	0.53 (.000)	0.54 (.000)
Cites - betw	1.03 (.000)	1.05 (.000)	1.05 (.000)
N	29478	17340	17340
rho	0.66	.66	0.67

Note: Dependent variable is the existence of patent equivalent of patent k in country j. Heteroscedasticity-consistent p-values in parentheses. For firm groups, firms without employees are reference group. Note that the cost coefficient is multiplied with 1000. It was originally reported in USD.

6. Summary and concluding remarks

We have presented trends in international patenting based on a database on Swedish patents and their international equivalents. We also modeled international patenting as the result of a strategy where gains and costs were traded off against each other. The model predicts that equivalents depend on market size, growth, patent costs and patent specific variables. Our empirical results indicate important variables that explain international patenting. First, more valuable patents have more equivalents. Second, variables that indicate technological interaction are important. Patent citations indicate possible links between the original patent and subsequent external technological activities. In the literature citations are used both as indicators of technological rivalry and as indicators of private and social values of the cited patents. This is in line with our findings about the effect of patent citations (both within technologies and between technologies).

Also the country specific variables have estimates in line with expectations. Market size, GDP per capita, growth and distance have coefficients with expected signs and significance. Also R&D intensity is positive and significant in line with our expectations. Patent costs influence negatively as expected, but (probably) due to data quality, the significance of the estimated coefficient is fragile.

In future work we intend to extend the study. We intend to use information about technology classes in the database. Since patenting is known to vary much between industries (Levin et *al*, 1987), we expect this to be important. Second, we will include overlap in R&D and in industrial specialization between Sweden and the country in question in order to better reflect the probability that an invention will be marketed and that it will imitated.

Appendix – about the data

Country	EPO member in 1998	Costs available
Austria	1	Yes
Australia	0	Yes
Belgium	1	No
Bulgaria	0	No
Brazil	0	Yes
Canada	0	Yes
Switzerland	1	Yes
China	0	No
Cyprus	1	No
Czech Republic	0	No
Germany	1	Yes
Denmark	1	Yes
Estonia	0	No
EPO			Yes
Spain	1	Yes
Finland	1	Yes
France	1	Yes
United Kingdom	1	Yes
Greece	1	Yes
Hong Kong	0	No
Hungary	0	No
Ireland	1	No
Italy	1	Yes
Japan	0	Yes
Korea, Rep.	0	Yes
Luxembourg	1	Yes
Monaco	0	No
Netherlands	1	Yes
Norway	0	Yes
New Zealand	0	Yes
Poland	0	No
Portugal	1	No
Romania	0	No
Russian	0	No
Taiwan	0	Yes
United States	0	Yes

Appendix. Derivation of eq. 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) $$q_{jt}{}^* = -\ln\left(1 - \frac{C_{jt}\left(r - g_j\right)\left(r + k - g_j\right)}{Y_{jt} k}\right)$$

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