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Patent value indicators and technological innovation

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Abstract
I provide empirical evidence that patent value indicators can identify technological innovation among inventors and small- and medium-sized enterprises in Sweden. Survey data on the commercialization of patents are related to patent value indicators (patent renewal, patent family size and forward citations) from archival sources. Among the patent value indicators, both the length of patent renewal and the size of the patent family indicate that a patent has been commercialized. Patent renewal for at least 6 years is sufficient to predict an accurate probability of commercialization. Furthermore, patent renewal is the only indicator revealing whether commercialization is successful. Forward citations have a moderate relationship with both commercialization and successful innovation, which may reflect the fact that citations are outside the control of the patentees or that forward citations measure spillovers rather than the private value. Although the correlations of the patent value indicators with technological innovation are noisy, this study provides stronger empirical support for the true relative value of different indicators with respect to innovation.

Keywords Patents · Patent value indicators · Commercialization · Technological innovation · Profitability · Patent renewal · Patent family size · Forward citations · SMEs

JEL O31 · O34

1 Introduction

Patent statistics are often used by policymakers to measure the output of research and development (R&D) and innovation. For example, the European Innovation Scoreboard index is based on multiple indicators of innovation, including education, scientific publications, R&D expenditures, Patent Cooperation Treaty (PCT) applications and knowledge-intensive exports (European Commission 2020). This index

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can be used to determine how competitive the EU is compared with other OECD countries and to determine the strengths and weaknesses of individual EU Member States. Furthermore, the United Nations (2019) and WIPO (2019) regularly present patent statistics in their yearbooks.

A weakness of using patent data is that innovation is defined in a narrow sense: Patents are considered product or process innovations only if they are commercialized. This approach excludes innovations linked to changes in the organizational structure or to new marketing methods, as defined in the OSLO manual (OECD 1997, 2005).[1] However, a strength in using patents as an innovation indicator is that the commercialization of a patent automatically means that a technological innovation is introduced since patents are granted only to *novelties and inventions*.[2] A practical problem is that almost no patent databases contain information on which patents have been commercialized, i.e., which specific patents have been introduced as innovations in the market. Consequently, prior research has instead relied on several value indicators to identify patents deemed valuable (see van Zeebroeck 2011 and Thoma 2014 for overviews). Among these value indicators, *patent renewal*, *patent family size*, *forward citations* and *oppositions* are the most frequently used. How these patent value indicators are related to the commercialization of patents is never or seldom examined in the literature.

This paper aims to show which traditional patent value indicators can be used as indicators for technological innovations in the Schumpeterian sense (introduction of an invention in the market). The main contribution is to relate the patent value indicators mentioned above from archival sources to survey measures of patent commercialization (technological innovation) and successful innovation (for the patentee). To the best of our knowledge, such a study has never been undertaken. Previous studies have analyzed different measures of patent value, not commercialization (Harhoff et al. 1999; Fischer and Leidinger 2014; Thoma 2014; Abrams et al. 2019). For this purpose, we use a unique database on patents granted in Sweden owned by small firms and individuals. The data set is based on a survey and contains information on *whether*, *when* and *how* (existing firm, new firm, licensed or sold) patents

[1] The introduction of the OSLO manual in 1997 and its extension in 2005 were important steps in the measurement of innovation output (OECD 1997, 2005). Its guidelines made it possible to collect harmonized and internationally comparable data on innovation output for the first time. In the OSLO manual, innovations include not only product and process innovations but also innovations related to organizational change/business practices and new marketing concepts/strategies (OECD 2005). An example of surveys based on this manual to identify innovations is the Community Innovation Survey (CIS) conducted by Eurostat (Gault 2013). In this survey, respondents provide information on four different types of innovations from the OSLO manual. However, since CIS is a cross-sectional survey, the main disadvantage is that the exact timing of the year of introduction of an innovation is not known (Mairesse and Mohnen 2010). Another disadvantage is that innovation measures are subjective in nature, as they depend on the judgment of respondents. Furthermore, the value of innovations is likely to be uneven across firms and industries, with random errors of classification and measurement in both qualitative and quantitative variables (Mairesse and Mohnen 2010). However, in contrast to innovation (input) expenditures, the share of sales due to new products can be regarded as relatively accurate, although the measure is rounded to five or ten percent (Mairesse and Mohnen 2010).

[2] The basic conditions for granting a patent are that the invention is novel, inventive, nonobvious and industrially applicable.

were commercialized as well as whether the commercialization was profitable for the patentee. Here, commercialization refers to the introduction of a product or process innovation in the market—a similar definition as used in the CIS surveys.[3] The database also contains traditional patent value indicators, such as patent renewal, forward citations and patent family size from archival sources.[4]

In the empirical part, we provide new estimates of how technological innovations are related to traditional patent value indicators by using different qualitative response models (the probit model and ordered probit model with sample selection). The estimations show that commercialization is strongly positively correlated with both patent renewal and patent family size but moderately positively correlated with forward citations. Furthermore, successful innovations are positively related to patent renewal in most cases. The results also show that one does not need to observe 20 years of renewal patterns to identify technological innovations. A patent that is renewed for at least 6 years is a good indication of a technological innovation. Similarly, patents renewed for at least 7−10 years indicate that an innovation is successful.

This paper is organized as follows. The theoretical background is outlined in Sect. 2, which presents different measures of innovations and patent value and explains what motivates their use. The database is described in Sect. 3. In Sect. 4, the statistical methods for relating patent value indicators to innovations are specified. The results of the estimations are then presented in Sect. 5, and the final section summarizes the conclusions of the study.

2 Discussion of concepts and traditional patent value indicators

2.1 Traditional patent value indicators

In the literature, four main indicators of patent value have been used: forward citations, patent family size, patent renewal and oppositions (van Zeebroeck 2011).[5] The grant decision has also been used as an indicator of patent value in analyses of patent applications. However, this indicator is not considered in the present study, which focuses solely on granted patents.

Forward citations In the patent literature, forward citations have frequently been used as a measure of patent value, despite skepticism about whether forward citations actually measure the private value of patents or spillover effects (Hall et al. 2007). Forward citations indicate the existence of downstream research efforts and a potential market for a patent (van Zeebroeck 2011). Trajtenberg (1990) argues that forward citations measure the social value of patents. For a specific patent, a higher

[3] In our survey, inventors were asked the following question: Did you introduce a product or process based on the patent in the market?

[4] Unfortunately, oppositions are not available for patents granted in Sweden.

[5] Some studies have also related the characteristics of patents with firm value (see, e.g., Griliches et al. (1987); Hall (1993), Lanjouw and Schankerman 2004).

frequency of citations by later patents is associated with larger spillover effects and, hence, higher social value. A patent can be cited at any time after the application date, even after it has expired. Harhoff et al. (1999) and Harhoff et al. (2003) show that there is a positive relationship between forward citations and the patentee's estimated value of the patents, although this relationship is somewhat noisy. Abrams et al. (2019) show that the relationship between patent value (measured as novel licensing data) and citations is an inverted-U shape, with fewer citations at the high end of value than in the middle.

Patent family size The number of patents in the patent family is an important indicator of the private value of patents (Putnam 1996). Since patent filing and enforcement are costly in many countries, only patents with a sufficiently high expected value are filed in many countries. However, once a patent is filed with any patent office, the patent owner must file patents with other offices within a year to expand the patent rights to other countries (the priority year). Lanjouw and Schankerman (2001a, b) and Harhoff et al. (2003) show that family size is positively correlated with patent or firm value. Fischer and Leidinger (2014) show that both forward citations and family size are positively related to patent value (measured as patent auction prices).[6] Although these factors explain only a small portion of the variance in patent value, the full model explains a large share of the variance in patent value.

Patent renewal Patent holders must pay an annual fee to keep their patents in force, and this fee increases over time until the maximum life span of 20 years is reached. According to Griliches (1990), rational owners will renew their patents only if it is economically profitable to keep them. Several previous studies have estimated the private value of patents by using the renewal scheme of patents (see, e.g., Pakes (1986); Schankerman and Pakes (1986) and successive studies). Pakes and Schankerman (1984) (and successive studies) show that most patents have a low value and depreciate quickly. Only a few patents have a significantly high value and last for the maximum period.

Oppositions A fourth traditional patent value indicator addresses whether oppositions have been filed against a granted patent. Oppositions by a third party signal a patent's potential value in a given market. Therefore, oppositions indicate that there is a potential market for the patent and that the patent is sufficiently important to justify the costs and risks associated with a dispute (Lanjouw and Schankerman 1997; 2001a; b, Harhoff et al. 2003; van Zeebroeck 2011).

Further measures of patent value van Zeebroeck and van Pottelsberghe (2011a; b) conclude that filing routes and drafting strategies can be used to identify patent value by analyzing 250 000 granted EPO patents. Their estimations show that the number of claims filed, the drafting of assembly of several priority filings, the choice of the PCT route and the patents of divisional applications are positively related to the renewal length, family size, forward citations and oppositions.[7]

[6] Fischer and Leidinger (2014) did not include patent renewals in the model to explain patent value.

[7] De Rassenfosse et al. (2013) present a new patent-based indicator of inventive activity on country level. The indicator counts all priority patent applications filed by a country's inhabitants, regardless of the patent office in which the patent application is filed. This indicator covers more inventions than PCT or triadic family counts.

2.2 Commercialization of patents

One strength of using patents as an indicator of innovation is that the commercialization of a patent automatically means that a technological innovation is introduced since patents must be *novel and inventive*. In the few available studies that have measured the commercialization of patents, Morgan et al. (2001) found a commercialization rate of 47 percent for American patents. Griliches (1990) finds a commercialization rate of 55 percent but reports a commercialization rate as high as 71 percent for small firms and inventors. Morgan et al. (2001) define commercialization as the commercialization of a product or process or the granting of a licensing contract, whereas Griliches (1990) defines commercialization as the commercial use of a patent. Neither of these studies required the commercialization of the patent to be profitable for the owner.

Svensson (2007, 2013) analyzes the commercialization pattern of patents based on the same data set that is used in the present study. The main question was the probability of commercialization and the renewal length of patents subsidized by government research programs compared to a control group. Other studies have also used this data set. Braunerhjelm and Svensson (2010) investigate the performance of different commercialization strategies (entering the market or licensing/selling the patent). Maurseth and Svensson (2020) analyze the transfer of tacit knowledge when patents are commercialized. In the present study, the data set is used in another way. I attempt to determine which traditional patent value indicators can be used to identify technological innovation (commercialization) and successful innovations (profitable commercialization).

3 Database

A detailed data set of patents granted in Sweden to Swedish small- and medium-sized enterprises (SMEs) (fewer than 1,000 employees) and individual inventors in 1998 is used. The data set is based on a survey conducted in 2003–2004, where all 1,082 Swedish patents granted to Swedish SMEs and individuals in 1998 were included in the population.[8] The collection of the database was part of a larger scientific project that examined the commercialization process of patents in SMEs and analyzed the effects of various government subsidies to SMEs on the commercialization outcome. Several articles in this project have been published (see Sect. 2.2).

The survey response rate is 80 percent, implying that the sample consists of 867 patents.[9] The data set is unique because it contains information on *whether*, *when* and *how* the patent has been commercialized as well as the profitability of

[8] In 1998, 2,760 patents were granted in Sweden. A total of 776 of these patents were granted to foreign firms, 902 to large Swedish firms with more than 1,000 employees and 1,082 to Swedish individuals and SMEs with less than 1,000 employees.

[9] For a more thorough description of the data set, data collection and nonrespondents, see Svensson (2007).

the commercialization for the patentees. The data set has been complemented with information on patent renewal, patent family, forward citations and filing routes from the Espacenet (2019) website. Thus, the database includes information on several traditional patent value indicators.

In the present study, commercialization is defined to indicate that a product or process innovation based on a patent has been introduced in the market—by the inventor, the inventing firm or an external firm that has licensed or acquired the patent. This definition is similar to that used in previous survey studies (Griliches 1990; Morgan et al. 2001) and similar to the definition used in the CIS surveys, i.e., that the patent has been used commercially.

The 867 patents and the patent commercialization rate are described across firm groups in Table 1.[10] As many as 408 patents (47 percent) were granted to individual inventors, and 116, 201 and 142 patents were granted to medium-sized firms (101–1,000 employees), small firms (11–100 employees) and micro-firms (2–10 employees), respectively.[11] The commercialization rate for the whole sample is 61 percent. The higher commercialization rate in the present study compared to that found in previous studies likely results from the focus solely on patents owned by small firms and individual inventors, as large (multinational) firms have many more defensive patents than small firms. As shown in Table 1, the commercialization rate for firm groups is between 66 and 74 percent, whereas the rate for individuals is 51 percent.[12]

The inventors were asked to estimate whether the commercialized invention would yield a profit, break-even or result in a loss for the patentee. If they did not know, the reply was registered as a missing value (an uncertain outcome).[13] In Table 2, discrete values for the outcome in terms of profit across firm groups are presented.[14] As shown in the table, outcomes differ substantially across firm groups, with the group of individual inventors having the least favorable outcome.

[10] Turning to the filing routes, only eight of 867 patents were first filed abroad, and all of these were in the USA. No patent was filed first with the EPO or WIPO and thereafter in Sweden. This pattern markedly contrasts with the filing routes undertaken by multinationals (see, e.g., Guellec and van Pottelsberghe 2000). Various explanations may account for this result; for example, the patentees in the database used in this study are individuals and small firms, and the data cover patent filings in the 1990s, when it was still common to first file patents in the home country.

[11] The grouping of firm size classes is based on the grouping in the survey.

[12] A contingency table test suggests that this difference in the commercialization rate between firms and individuals is statistically significant at the one percent level (Chi-square value of 30.55 with 3 d.f.).

[13] For the vast majorities of patents, commercialization had reached a stage such that there was no uncertainty about the patent's performance in 2003. In 2007, importation on the profitability of commercialization was updated via phone calls to inventors who had earlier announced an uncertain outcome.

[14] It would have been desirable to measure the outcome in terms of money, but such information was impossible to collect. Estimating profit flows is very complicated because most firms have many products in their statement of accounts, and many individual inventors do not have any statement of accounts at all.

4 Estimation techniques and explanatory variables

In this section, I present the estimation techniques that I use to test the relationships between the traditional patent quality indicators and (1) the probability of an innovation (the commercialization of a patent) and (2) the probability of a successful innovation for the patentee.

4.1 Probability of an innovation

The dependent variable Com_i represents whether patent i has been commercialized. It is dichotomous in nature and takes the value of 1 if a technological innovation has been introduced in the market and 0 otherwise. Therefore, a standard probit model based on the cumulative normal distribution function is used to predict variation in the dependent variable. The model can be written as:

$$\begin{aligned} c_i^* &= X_i\beta + \nu_i, \\ c_i &= 1 \quad \text{if } c_i^* > 0 \text{ and } 0 \quad \text{otherwise} \end{aligned} \tag{1}$$

where c_i^* is a latent index, c_i is the selection variable indicating whether the patent is commercialized, X_i is a vector of explanatory variables that influence the probability that the patent is commercialized, β is a vector of parameters to be estimated and $\nu_i \sim N(0, 1)$.

4.2 Probability of a successful innovation

The dependent variable *Success* measures the performance of the commercialization for the original patent owner in terms of profit. This variable can take three different discrete values, denoted by index k:

- Profit, $k=2$;
- Break-even, $k=1$;
- Loss, $k=0$.

Since the three alternatives can be ordered, an ordered probit model is applied and is described in detail in Appendix A (Greene 1997). A possible objection against the sample and the chosen statistical model is that the patents, which are commercialized, do not constitute a random sample of patents but instead have specific characteristics that led them to be commercialized in the first place, potentially resulting in misleading parameter estimates. An appropriate statistical model is therefore an ordered probit model with sample selectivity based on the commercialization decision; see also Appendix A (Greene 2002).

Table 1 Commercialization of patents across firm sizes, number of patents and percent

Kind of firm where the invention was created	Commercialization		Total	Percent commercialized (%)
	Yes	No		
Medium-sized firms (101–1000 employees)	77	39	116	66
Small firms (11–100 employees)	137	64	201	68
Micro-firms (2–10 employees)	105	37	142	74
Inventors (1–4 inventors)	207	201	408	51
Total	526	341	867	61

Table 2 Performance of the commercialization across firm groups, number of patents and percent

Kind of firm where the invention was created	Performance				Total
	Profit	Break-even	Loss	Missing value	
Medium-sized firms	55	18	3	1	77
Small firms	97	24	15	1	137
Micro-firms	60	17	27	1	105
Inventors	69	47	87	4	207
Total	281	106	132	7	526
Percent	53.4%	20.2%	25.1%	1.3%	100.0%

4.3 Explanatory variables

In all estimations, patent value indicators that are available in common patent databases (e.g., PatStat (2020) EPO database) are included.

Forward citations. The total number of forward citations that *a patent and its patent equivalents* have received during the period of five years after publication is used in two ways (as suggested by van Zeebroeck 2011). Self-citations are excluded from these measures. First, *all forward citations* that a patent and its equivalents have received within five years of publication, here called *Citations 1*, are used. Some patent offices, such as the United States Patent and Trademark Office (USPTO), cite patents more frequently than other patent offices. Therefore, the number of forward citations that the patent and its equivalents have received within five years of publication *from PCT applications and patents granted by the European Patent Office (EPO)*, here called *Citations 2*, is also used. Data on forward citations were collected from Espacenet (2019).

Patent family size The variable *Family* measures the total number of foreign granted patents in the patent family covering similar technical content.[15] Thus, the INPADOC definition of patent family is used.

[15] Patents applications that have not been granted are excluded.

Triadic patents Patents abroad should not be regarded equally, as host countries vary in market size. In the database, foreign patent filings are dominated by large markets. *EPO*, *USA* and *Japan* are additive dummies that equal 1 if there is an administrative patent at EPO, a US patent or a Japan patent, respectively, and 0 otherwise.

Patent renewals The variable *Renewal* measures the number of years of patent renewal, measured from the start of the priority year. The maximum value is 20 years. However, we do not wish to wait 20 years to identify an innovation. Therefore, additional dummies for the length of renewal are also used. For example, the dummy *Renewal5* equals 1 if the patent is renewed for at least 5 years and 0 otherwise, *Renewal6* equals 1 if renewed for at least 6 years, etc.

Data on oppositions are not available for Swedish patents at Espacenet (2019).[16] The traditional patent quality indicators are also squared in some of the estimations to determine whether a nonlinear relationship exists between these quality indicators and *Com/Success*. Definitions and descriptive statistics for the dependent and explanatory variables are shown in "Appendix B, Table 12".

Control variables In all estimations, we use control variables in the form of industry class, region and time dummies as follows. Since patenting and innovations are known to vary greatly between industries and technology classes (Levin et al. 1987), we include additive dummies for 30 different industry classes designated by Breschi et al. (2004).[17] These industry classes are based on the IPC system, and a patent may belong to several different IPC classes. However, it is not possible to determine the main IPC class because the classes are listed in alphabetical order for each patent in Espacenet (2019). Therefore, a patent in the database used in this study may belong to as many as four different industry classes. Consequently, the 30 industry dummies are not mutually exclusive.[18] The data are divided into six different kinds of regions according to NUTEK (1986): large-city regions, university regions, regions with important primary city centers, regions with secondary city centers, small regions with private employment, and small regions with government employment. Five additive dummies are included in the estimations for these six groups. Additive dummies are also included for different application years since the business cycle may affect when and whether a patent will be commercialized. The data have five application year periods (1985–1990, 1991–1992, 1993–1994, 1995–1996 and 1997–1998), and four additive dummies are assigned for these periods.[19]

[16] Oppositions are only available for those Swedish patents that have a sister patent at EPO.

[17] A given IPC class can be associated with several industry sectors. In the study, we use the most likely industry class associated with a specific IPC class (Breschi et al. (2004). The alternative would be to use IPC classes in the estimations instead. We have experimented with this alternative. However, even using dummies on a three-digit level for IPC classes would create too many dummies and too few patents in each IPC class. As a result, such estimations breakdown and do not converge.

[18] In some estimations, we had to reduce the number of industry classes because of the limited number of observations in each class. For example, only 25 classes are included when the ordered probit model is estimated.

[19] Note that only one patent was applied for in 1985 and in 1986, respectively, and no patents during the 1987–1989 period. Therefore, 1985, 1986 and 1990 have been merged into one group.

Furthermore, we include a range of firm- and patent-specific factors that might affect the decision of commercialization and the profit level of commercialization in every second model, for example, firm size, financing during the R&D phase, complementary patents, ownership, number of inventors, sex and ethnic factors ("Appendix Table 12"). These explanatory variables were included when estimating the commercialization decision in Svensson (2007) and the profitability of commercialization in Braunerhjelm and Svensson (2010).

5 Results of the estimations

5.1 Bivariate analysis

As many as 318 (of 867) patents had forward citations according to the first measure, but only 209 had forward citations from the PCT or EPO. Some evidence suggests a positive relationship between commercialization and the two measures of forward citations. The Spearman rank correlations between commercialization and the citation variables are 0.14 and 0.07, which are significant at the 1 and 5 percent levels, respectively (Table 3).

The 867 patents in the database together have 1,734 granted patents abroad in their families, for an average of exactly two foreign patents in the family per Swedish patent. Only 345 (40 percent) of the 867 patents have at least one foreign patent in their family. Moreover, given that a patent has at least one patent abroad, the average number of foreign patents is 5.0. The maximum number of foreign patents for a given patent is 24. The Spearman rank correlation between commercialization and family size is 0.24, which is significant at the 1 percent level (Table 3).

Triadic patents (i.e., patents that are filed in the three largest patent offices in the world—the EPO, the USPTO and the Japanese patent office) should be especially valuable. The database contains 79 Triadic patents, and 113 patents were filed in at least two Triadic markets. Moreover, there are 224 patents in the USA and 141 in Japan, as well as 217 EPO patents. EPO patents must be validated in individual member countries, and EPO patents resulted in 1,104 individual patents in the EPO member countries, for an average of 5.1 individual patents per EPO patent.[20] The EPO patents in the database used in this study are filed most frequently in Germany, Great Britain and France—the large EPO countries.[21] Thus, foreign patents in the family are not distributed randomly across countries.[22] As shown in Table 4, the results reveal a strong positive relationship between commercialization and an EPO patent, a US patent, patents in at least two Triadic markets and a Triadic patent

[20] This average number of countries is the same as that for EPO patents in general (van Zeebroeck 2011).

[21] Only 30 patents in the database were filed directly at the national patent offices in the EPO area without filing an EPO patent first.

[22] van Zeebroeck and van Pottelsberghe (2011b) show a strong positive correlation between market size and the probability that an EPO patent will be validated in a country. The skewed country distribution of patents above indicates that country characteristics are important for international patenting.

(EPO, the USA and Japan). Chi-square tests indicate that the relationships are highly significant in all four cases; however, commercialization has a stronger relationship with EPO and US patents than with Triadic patents.

Considering the renewal pattern, 407 patents (47 percent) expired before 10 years, whereas 460 (53 percent) were renewed for at least 10 years. As many as 133 patents (15 percent) were renewed the maximum period of 20 years. The share of commercialized patents is higher for longer-lasting patents. The Spearman rank correlation between patent renewal and commercialization is 0.26, which is clearly significant at the 1 percent level (Table 3).

Summarizing the Spearman rank correlations in Table 3, commercialization (indicating an innovation) is clearly more strongly correlated with family size and patent renewal than with forward citations. Moreover, patent renewal, family size and forward citations are all positively and significantly correlated with each other.

Table 5 reports the results regarding the correlations between the profitability of patent commercialization (three levels, as defined in a previous section) and the traditional patent value indicators. Here, only commercialized patents are included in the analysis. The correlations between the commercialization variable and the traditional patent value indicators in Table 5 are all positive but somewhat weaker than those in Table 3.

5.2 The probability of a technological innovation

In the statistical models, the estimated relationships are interpreted as partial correlations and not as causality. The results of the probit estimations are shown in Table 6. Almost 70 percent of the observations are correctly predicted with respect to commercialization (*Com*). Several variants of the model are estimated. For example, several control variables are included: Forward citations are alternatively represented by *Citations 1* and *Citations 2* (all citations vs. only citations from the EPO and PCT), and *Family* is replaced by additive dummies for patents in the Triadic markets.

Both the family size and the length of patent renewal have a strong positive relationship with the probability of commercialization, and the estimated parameters are significant at the 1 percent level (*Renewal* in all models and *Family* in Models A, B, E and F). However, when family size is substituted for dummies for EPO, US and Japanese patents, the parameters of these dummies are not significant (Models C, D, G and H).[23] Notably, the estimated parameters of forward citations are never significant.[24] The marginal effects of the explanatory variables on the probability of

[23] The model is not improved by including an additive dummy for a Triadic patent instead of the three dummies for EPO, US and Japanese patents.

[24] Nonlinear relationships might exist between commercialization and some of the traditional patent value indicators. For example, the probability of commercialization may increase with family size, but the rate of increase may decline for high numbers. Estimations with squared values of the number of citations, the family size and the number of years of renewal do not alter the results. None of the squared variables is significantly related to commercialization. Likelihood ratio tests between the estimations in Table 6 and those with squared values are not significant, indicating that the inclusion of squared values

Table 3 Correlation matrix between commercialization and patent value indicators, Spearman rank parameters

Citations 1 (number, all)	0.14 ***			
Citations 2 (number, EPO + PCT)	0.07 **	0.78 ***		
Family size (number)	0.24 ***	0.61 ***	0.41 ***	
Renewal (years)	0.26 ***	0.21 ***	0.15 ***	0.38 ***
	Com	Citations 1	Citations 2	Family size

$n = 867$. ***, ** and * indicate significance at the 1, 5 and 10% level, respectively

Table 4 Relationship between commercialization and patents in large markets

Commercialized	EPO patent		US patent		Patent in 2 or 3 Triadic areas		Triadic patent		Total
	No	Yes	No	Yes	No	Yes	No	Yes	
No	289	52	285	56	314	27	322	19	341
Yes	361	165	358	168	440	86	466	60	526
Total	650	217	643	224	754	113	788	79	867
Chi-square test	28.65 ***		26.00 ***		12.98 ***		8.51 ***		

***, ** and * indicate significance at the 1, 5 and 10% level, respectively. A Triadic patent means that a patent was granted at EPO, in the USA and in Japan

Table 5 Correlation matrix between profitability of commercialization and value quality indicators, Spearman rank parameters

Citations 1 (number, all)	0.10 **			
Citations 2 (number, EPO + PCT)	0.07	0.75 ***		
Family size (number)	0.16 ***	0.57 ***	0.37 ***	
Renewal (years)	0.31 ***	0.14 ***	0.12 ***	0.32 ***
	Success	Citations 1	Citations 2	Family size

$n = 519$. ***, ** and * indicate significance at the 1, 5 and 10% level, respectively

an innovation (calculated around the means of X) are shown in Table 7. As shown, if family size increases by one foreign patent, then the probability of an innovation increases by 1.9–2.2 percentage points. If the patent is renewed for one more year, the probability of an innovation increases by 2.0–2.4 percentage points (Table 7).

To identify technological innovations, one would ideally wait no more than 10 years to observe the renewal pattern rather than waiting 20 years. Therefore,

Footnote 24 (continued)
does not improve the models. Furthermore, the share of correct predictions of Com does not improve. These nonlinear estimations are available from the author upon request.

Table 6 Results of the probit estimations

Dependent variable = Com								
Statistical model = Probit model								
Explanatory variable	A	B	C	D	E	F	G	H
Citations 1	0.024 (0.020)	0.024 (0.020)	0.018 (0.020)	0.021 (0.021)				
Citations 2					0.027 (0.049)	0.020 (0.048)	0.017 (0.048)	0.016 (0.047)
Family	0.053*** (0.017)	0.049*** (0.018)			0.056*** (0.017)	0.052*** (0.018)		
EPO			0.127 (0.143)	0.073 (0.147)			0.135 (0.143)	0.087 (0.147)
USA			0.184 (0.146)	0.152 (0.151)			0.217 (0.141)	0.190 (0.146)
Japan			0.202 (0.166)	0.230 (0.172)			0.197 (0.166)	0.223 (0.171)
Renewal	0.060*** (0.0097)	0.053*** (0.010)	0.063*** (0.0097)	0.058*** (0.010)	0.061*** (0.0097)	0.054*** (0.010)	0.063*** (0.0097)	0.058*** (0.010)
FIRM1		− 0.17 (0.23)		− 0.19 (0.23)		− 0.15 (0.23)		− 0.17 (0.23)
FIRM2		0.068 (0.16)		0.055 (0.16)		0.073 (0.16)		0.057 (0.16)
FIRM3		0.37** (0.15)		0.37** (0.15)		0.38** (0.15)		0.37** (0.15)
GOVFIN		− 0.0088*** (0.0028)		− 0.0087*** (0.0028)		− 0.0088*** (0.0028)		− 0.0086*** (0.0028)
PRIVFIN		− 0.0013 (0.0037)		0.0011 (0.0038)		0.0014 (0.0037)		0.0011 (0.0038)
OTHFIN		− 0.0029 (0.0042)		− 0.0032 (0.0042)		− 0.0029 (0.0042)		− 0.0032 (0.0042)

Table 6 (continued)

Dependent variable = Com

Statistical model = Probit model

Explanatory variable	A	B	C	D	E	F	G	H
UNIV		− 0.66**		− 0.69**		− 0.66**		− 0.69**
		(0.33)		(0.33)		(0.33)		(0.33)
KOMPL		0.42***		0.41***		0.43***		0.42***
		(0.13)		(0.13)		(0.13)		(0.13)
MOREPAT		0.065		0.069		0.063		0.067
		(0.10)		(0.10)		(0.10)		(0.10)
OWNER		− 0.14		− 0.15		− 0.13		− 0.14
		(0.17)		(0.17)		(0.17)		(0.17)
INVNMBR		− 0.067		− 0.072		− 0.069		− 0.074
		(0.078)		(0.078)		(0.078)		(0.078)
SEX		0.21		0.25		0.20		0.25
		(0.35)		(0.35)		(0.35)		(0.35)
ETH		− 0.20		− 0.20		− 0.18		− 0.17
		(0.32)		(0.35)		(0.31)		(0.31)
Dummies:								
Industries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	− 520.4	− 496.8	− 521.4	− 498.0	− 521.0	− 497.5	− 521.7	− 498.5
Share of correct predictions	66.9	69.0	67.4	69.6	67.5	69.1	66.8	69.4

$n = 867$. Standard errors are in parentheses. ***, ** and * indicate significance at the 1, 5 and 10% level, respectively. Parameter estimates of intercept and industry class dummies are not reported but are available from the author on request

Table 7 Marginal effects on the probability of an innovation

Dependent variable = *Com*

Statistical model = Probit model

Explanatory variable	A	B	C	D	E	F	G	H
Citations 1	0.0091 (0.0076)	0.0088 (0.0078)	0.0070 (0.0077)	0.0077 (0.0080)				
Citations 2					0.010 (0.019)	0.0068 (0.018)	0.0069 (0.018)	0.0054 (0.018)
Family	0.021*** (0.0065)	0.019*** (0.0067)			0.022*** (0.0064)	0.020*** (0.0066)		
EPO			0.049 (0.053)	0.030 (0.055)			0.052 (0.053)	0.035 (0.055)
USA			0.069 (0.054)	0.057 (0.056)			0.081 (0.052)	0.071 (0.053)
Japan			0.078 (0.060)	0.086 (0.061)			0.076 (0.060)	0.083 (0.061)
Renewal	0.023*** (0.0037)	0.020*** (0.0039)	0.024***(0.0037)	0.021*** (0.0039)	0.023*** (0.0037)	0.020*** (0.0039)	0.024*** (0.0037)	0.021*** (0.0039)

$n = 867$. The marginal effects are calculated around the means of the X's. Standard errors are in parentheses

***, ** and * indicate significance at the 1, 5 and 10% level, respectively

Table 8 Results of the probit estimations with renewal dummies, marginal effects

Dependent variable = *Com*												
Statistical model = Probit model												
Explanatory variable	Model B, One renewal dummy, marginal effects							Model B, Two renewal dummies, marginal effects [a]				
Citations 1	0.0099 (0.0079)	0.0097 (0.0079)	0.0083 (0.0078)	0.0093 (0.0078)	0.0094 (0.0078)	0.0097 (0.0079)	0.0094 (0.0078)	0.0083 (0.0078)	0.0083 (0.0078)	0.0083 (0.0078)	0.0081 (0.0078)	0.0091 (0.0078)
Family	0.031*** (0.0063)	0.030*** (0.0064)	0.027*** (0.0064)	0.027*** (0.0064)	0.027*** (0.0065)	0.027*** (0.0065)	0.026*** (0.0066)	0.027*** (0.0064)	0.026*** (0.0065)	0.026*** (0.0065)	0.025*** (0.0066)	0.026*** (0.0066)
Renewal4	0.144* (0.080)							-0.015 (0.088)				
Renewal5		0.105* (0.062)										
Renewal6			0.197*** (0.051)					0.202*** (0.059)	0.173*** (0.062)	0.179*** (0.054)	0.170*** (0.056)	
Renewal7				0.140*** (0.045)								0.107** (0.054)
Renewal8					0.117*** (0.042)				0.034 (0.051)			
Renewal9						0.098** (0.040)				0.031 (0.046)		
Renewal10							0.108*** (0.040)				0.053 (0.044)	0.055 (0.048)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry classes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log likelihood	− 505.3	− 505.4	− 499.3	− 502.1	− 506.5	− 504.1	− 503.4	− 499.3	− 499.1	− 499.1	− 498.6	− 501.4

Table 8 (continued)

Dependent variable = *Com*												
Statistical model = Probit model												
Explanatory variable	Model B, One renewal dummy, marginal effects							Model B, Two renewal dummies, marginal effects [a]				
Share of correct predictions	66.6	67.0	68.4	67.7	68.4	67.4	67.1	68.6	68.6	68.4	68.0	67.2

$n = 867$. Standard errors are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% level, respectively. Parameter estimates of intercept, control variables, industry class dummies, region dummies and time dummies are not reported but are available from the author on request. Similar results for the renewal dummies were achieved in Models A, C–H. These estimations are available from the author upon request

[a] Only the five (of 14) combinations of renewal dummies with the highest log-likelihood value are shown

Renewal is replaced by the additive dummy *RenewalX*, which shows whether the patent is alive after X years (with the limits: 4 years $\leq X \leq$ 10 years). The results revealed that the best fit (log -likelihood value) in Models A−H was achieved if the dummy *Renewal6* was used, as shown in the left part of Table 8. A patent that is renewed for at least six years has a 20 percentage points higher probability of being commercialized than those that are not renewed for six years. When two renewal dummies are used, the combination of *Renewal6* and *Renewal10* yields the highest log-likelihood value in Models A−H.[25] *Thus, after 6 years of renewal, one can already obtain a good indication of whether a technological innovation has been introduced in the market.*

5.3 The probability of a successful innovation

The results of the ordered probit estimations are presented in Table 9. The estimated parameter ρ is significant in seven of eight models, indicating that there is a sample selection problem and that the model should be estimated in two steps. Regarding the explanatory variables, forward citations are not related to successful commercialization. Moreover, family size is either positively or negatively related to *Success*, but the estimated parameter is never significant. However, the results show that a US patent is positively related to *Success*, whereas a Japanese patent is strongly negatively related to *Success*. Additionally, the length of patent renewal is strongly and positively related to successful commercialization, with a significant estimated parameter at least at the 5 percent level in all models except Model D.

The marginal effects of the explanatory variables on different commercialization outcomes (*Success*) are depicted in Table 10. If a patent is renewed for one more year, then the probability of a successful innovation increases by 1.2 (Model B) or 1.4 (Model G) percentage points. Furthermore, the marginal effect of a Japanese equivalent is negative and significant. The marginal effects of the other explanatory variables are nonsignificant. Note here that the marginal effects of the dummy variables (*EPO*, *USA* and *Japan*) are relatively large because these effects are calculated when the dummies change from 0 to 1, i.e., from the minimum to the maximum value.

Moreover, we replace *Renewal* with *RenewalX* dummies. However, compared to the probit model, one must wait 7−10 years until it is possible to identify which innovations are successful. The results are found in Table 11. The model with *Renewal8* yields the highest log-likelihood value. Patents who are renewed for at least 8 years have an 11.4 percent higher probability of being successful than those who are not renewed 8 years. When two *RenewalX* dummies are used, the combination *Renewal6* and *Renewal8* gives the best fit.

[25] Compared to the alternatives (4, 6), (4, 7), (4, 8), (4, 9), (4, 10), (5, 7), (5, 8), (5, 9), (5, 10), (6, 8), (6, 9), (7, 9), (7, 10) and (8, 10) years.

Table 9 Results of the ordered probit estimations

Dep. variable: Success	Statistical model: Ordered probit model with sample selection							
Explanatory variables	A	B	C	D	E	F	G	H
Citations 1	0.015 (0.021)	0.0072 (0.026)	0.019 (0.019)	0.0025 (0.031)	0.035 (0.059)	− 0.033 (0.064)	− 0.021 (0.046)	− 0.035 (0.069)
Family	− 0.017 (0.014)	− 0.0074 (0.015)			0.065 (0.017)	0.0057 (0.014)		
EPO			0.088 (0.16)	0.19 (0.18)			0.044 (0.15)	0.20 (0.18)
USA			0.36** (0.16)	0.28 (0.21)			0.25 (0.17)	0.26 (0.19)
Japan			− 0.41** (0.18)	− 0.53*** (0.20)			− 0.39** (0.18)	− 0.51*** (0.20)
Renewal	0.037*** (0.012)	0.036** (0.015)	0.079*** (0.011)	0.046* (0.024)	0.058** (0.010)	0.031** (0.013)	0.041*** (0.016)	0.041** (0.020)
FIRM1		0.78*** (0.27)		0.85*** (0.29)		0.76*** (0.26)		0.84*** (0.29)
FIRM2		0.59*** (0.20)		0.71*** (0.24)		0.55*** (0.19)		0.68*** (0.22)
FIRM3		0.27*** (0.17)		0.38* (0.22)		0.23 (0.16)		0.35* (0.20)
GOVFIN		− 0.0032 (0.0047)		− 0.0059 (0.0061)		− 0.0018 (0.0043)		− 0.0050 (0.0055)
PRIVFIN		0.0039 (0.0039)		0.0054 (0.0042)		0.0036 (0.0037)		0.0051 (0.0041)
OTHFIN		0.0029 (0.0056)		0.0032 (0.0062)		0.0037 (0.0054)		0.0037 (0.0060)
UNIV		− 0.061 (0.79)		− 0.14 (0.97)		0.062 (0.79)		− 0.27 (0.96)
KOMPL		0.012 (0.14)		0.086 (0.19)		− 0.0020 (0.14)		0.068 (0.17)

Table 9 (continued)

Dep. variable: Success	Statistical model: Ordered probit model with sample selection							
Explanatory variables	A	B	C	D	E	F	G	H
MOREPAT		0.063		0.10		0.044		0.04
		(0.12)		(0.14)		(0.12)		(0.13)
OWNER		0.054		0.029		0.071		0.043
		(0.19)		(0.20)		(0.18)		(0.19)
INVNMBR		0.087		0.11		0.080		0.10
		(0.11)		(0.12)		(0.10)		(0.11)
SEX		− 0.058		− 0.069		− 0.11		− 0.10
		(0.35)		(0.38)		(0.34)		(0.37)
ETH		0.27		0.32		0.29		0.34
		(0.37)		(0.39)		(0.35)		(0.38)
Intercept ω (threshold value)	0.55	0.15	0.45	− 0.18	0.57	0.26	0.45	− 0.047
	0.50	0.60	0.55	0.69	0.50	0.57	0.55	0.66
Dummies:								
Industries	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ρ	− 0.92***	− 0.79***	− 0.81***	− 0.49	− 0.93***	− 0.89***	− 0.80***	− 0.61*
Log Likelihood Test vs. restricted model	− 979.4	− 927.3	− 977.8	− 924.3	− 981.1	− 927.3	− 978.6	− 924.3
	5.41**	2.90*	2.04	0.54	5.94***	4.73**	2.10	0.33

$n = 860$. Standard errors are in parentheses. ***, ** and * indicate significance at the 1, 5 and 10% level, respectively. Parameter estimates of industry class, region and time dummies as well as estimations without sample selection are not reported but are available from the author on request

Table 10 Marginal effects on probability of successful innovation in the ordered probit estimations

Dependent variable = *Success*

Statistical model: Ordered probit model with sample selection

Explanatory variables	Model B			Model G		
	P(0)	P(1)	P(2)	P(0)	P(1)	P(2)
Citations 1	– 0.0015	– 0.0010	0.0025			
Citations 2				0.0045	0.0026	– 0.0071
Family	0.0015	0.0010	– 0.0025			
EPO [a]				– 0.0096	– 0.0055	0.015
USA [a]				– 0.053	– 0.031	0.084
Japan [a]				0.086**	0.048**	– 0.134**
Renewal	– 0.0074***	– 0.0049***	0.012***	– 0.0089***	– 0.0052***	0.014***

***, ** and * indicate significance at the 1, 5 and 10% level, respectively. All marginal effects are calculated around the means of the X's. The sum of the marginal effects on the probabilities equals zero

[a] Marginal effect on probabilities when dummy variable increases from 0 to 1

Table 11 Results of the ordered probit estimations with renewal dummies, marginal effects

Dependent variable = Success

Statistical model: Ordered probit model with sample selection, marginal effects

Explanatory variables	Model B, One renewal dummy				Model B, Two renewal dummies		
	P(2)	P(2)	P(2)	P(2)	P(2)	P(2)	P(2)
Citations 1	0.0011	0.0011	0.0012	0.0015	0.0014	0.0014	0.0018
Family	0.00047	– 0.00029	– 0.00014	– 0.00050	– 0.0014	– 0.0013	– 0.0011
Renewal5 [a]					0.080		
Renewal6 [a]	0,125**					0.078	0.128*
Renewal7 [a]		0,109**					
Renewal8 [a]			0,114**		0.102**	0.097*	
Renewal9 [a]				0,102**			
Renewal10 [a]							0.092
Industry classes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ρ	– 0.90***	– 0.93***	– 0.91***	– 0.84***	– 0.87***	– 0.85***	– 0.74***
Log likelihood	– 928.4	– 927.5	– 927.0	– 928.9	– 926.1	– 926.1	– 926.7

***, ** and * indicate significance at the 1, 5 and 10% level, respectively. All marginal effects are calculated around the means of the X's. Only the marginal effects on P(2), profitable innovation, are shown. P(1) and P(0) are available from the author upon request. Estimations were also undertaken with *Renewal4*, *Renewal5, Renewal6, Renewal7* and *Renewal8* in the left part of the table and with other combinations of *RenewalX* in the right part, but these estimations had lower log-likelihood values and are not shown

[a] Marginal effect on probabilities when dummy variable increases from 0 to 1

6 Concluding remarks

6.1 Main results

This study has empirically analyzed whether and how strong traditional patent value indicators are related to (1) the probability that an individual patent is commercialized (i.e., the probability that a technological innovation is introduced in the market) and (2) whether patent commercialization is successful. This study provides stronger empirical support for the true relative value of different individual patent value indicators with respect to technological innovation. To the best of my knowledge, such an analysis has never been presented in the existing literature. For the analysis, a unique database of patents granted in Sweden with information on the commercialization process of individual patents based on a survey is used. Simple correlations and contingency table tests show that both patent commercialization and successful innovations are positively correlated with patent renewal and patent family size but only moderately positively correlated with forward citations. Although statistically significant, the correlation parameters are somewhat noisy, never exceeding 0.33.

In the statistical models, we interpret the relationships as partial correlations. Patent renewal and family size primarily have positive relationships with the probability of a technological innovation, whereas the relationship between forward citations and the probability of an innovation is generally nonsignificant. However, the estimations also show that one does not need to observe the renewal pattern for 20 years. Patents renewed for at least six years signal an accurate probability of commercialization.

With respect to the profitability of commercialization for the patentee, only patent renewal is positively related to profitability. Moreover, one does not need to observe the renewal pattern over 20 years. Patents renewed for 7–10 years predict a relatively accurate probability of a profitable technological innovation.

Inventors must decide soon after patent application in which countries file a patent (priority year); by contrast, the renewal decision is updated every year. Therefore, it is not surprising that the probability of a successful innovation is primarily positively related to the renewal decision. The moderate relationship between commercialization and successful commercialization with forward citations should be interpreted with caution for three reasons. First, commercialization and successful innovation in this study measure the private value of the patent, whereas forward citations should be related to the social value (spillovers) of the patent (Trajtenberg 1990). Second, forward citations are out of the control of the patentees. Finally, even if commercialization is not profitable for the patentee, the invention might be profitable for society as a whole if competitors imitate and patent around the original patent. There are countless examples in history where inventors failed to make their invention profitable by choosing the wrong strategy and where subsequent inventors instead took the bulk of the cake. The result with respect to forward citations and private patent value is partly in line with the previous empirical literature. Previous studies have found a positive relationship between forward citations and patent value, although this relationship has never been very strong (Harhoff et al. 1999, 2003; Fischer and Leidinger 2014). Bessen (2008) concluded that the correlation between forward citations and patent value (renewals) is positive and statistically significant, but the former factor explains only a small portion of the variance in patent value.

6.2 Limitations

Since the database covers only patents owned by small firms and individuals, the results can be used to predict technological innovations and successful innovations only for patents owned by these groups. Larger firms likely have a higher share of noncommercialized patents, which are used for defensive purposes (blocking or negotiations) (Svensson 2002). However, this does not rule out that patent renewal and family size are also positively related to commercialization decisions for large firms.

Finally, the study and method are unable to identify technological innovations in all sectors. In some sectors, firms traditionally prefer to protect their invented technologies by relying on secrecy and circumspection or strong lead times rather than patents (e.g., the car industry). By contrast, other sectors, primarily in large service areas, rely on other intellectual property rights (e.g., copyright) to protect artistic and literary works.

Appendix A

The ordered probit model can be described as (Greene 1997):

$$y_i^* = X_i\alpha + \varepsilon_i \tag{A1}$$

where X_i is a vector of patent quality indicators and technology dummies; α is a vector of coefficients that indicates the influence of the independent variables on the profit level; and ε_i is a residual vector that represents the combined effects of unobserved random variables and random disturbances. The residuals are assumed to have a normal distribution, and the mean and variance are normalized to 0 and 1. The vector with the latent variable, y_i^*, is unobserved. The model is based on the cumulative normal distribution function, $F(X\alpha)$**,** and is estimated via maximum likelihood procedures. The difference between this model and the two-response probit model is that in this model a parameter (threshold value), ω, is estimated by α. The probabilities $P_i(y=k)$ for the three outcomes are:

$$\begin{aligned} &P_i(0) = F(-X\alpha),\\ &P_i(1) = F(\omega - X\alpha) - F(-X\alpha),\\ &P_i(2) = 1 - F(\overline{\omega} - X\alpha),\\ &\text{where } \sum_{k=0}^{2} P_i(k) = 1 \end{aligned} \tag{A2}$$

The threshold value, ω, must be larger than 0 for all probabilities to be positive.

To take account of selectivity, in the first step, a probit model estimates how different factors influence the decision to commercialize a patent (Greene 2002):

$$
\begin{aligned}
&d_i^* = X_i\theta + u_i \\
&d_i = 1 \quad \text{if } d_i^* > 0 \text{ and } 0 \quad \text{otherwise}
\end{aligned}
\tag{A3}
$$

where d_i* is a latent index; d_i is the selection variable, indicating whether the patent is commercialized; X_i is a vector of explanatory variables that influence the probability that the patent is commercialized; θ is a vector of parameters to be estimated; and u_i is a vector of normally distributed residuals with zero mean and a variance equal to 1.

From the probit estimates, the selection variable d_i is then used to estimate a full-information maximum likelihood model of the ordered probit model (Greene 2002). In addition, the first step probit model is re-estimated. The residuals [ε, u] are assumed to have a bivariate standard normal distribution and correlation ρ. There is selectivity if ρ is not equal to zero. Note that this specification is not a two-step Heckman model. No lambda is computed and used in the second step.

Appendix B

See Table 12

Table 12 Descriptive statistics of dependent and explanatory variables

Dependent variables	Definition	All observations ($n=867$)		Commercialized patents ($n=526$)	
		Mean	Std. dev	Mean	Std. dev
Com	Dummy that equals 1 if commercialization, and 0 otherwise	0.61	0.49	–	–
Success	Profitability of commercialization for the patentee. 2 = profit, 1 = break-even, 0 = loss	–	–	1.29	0.85
Explanatory variables					
Citations 1	Number of forward citations from all sources within five years after publishing	1.21	2.99	1.45	3.46
Citations 2	Number of forward citations from EPO and PCT within five years after publishing	0.44	1.15	0.50	1.32
Family	Patent family size (granted patents abroad)	2.00	3.79	2.64	4.32
EPO	Dummy that equals 1 if an administrative patent at EPO, and 0 otherwise	0.25	0.43	0.31	0.46
USA	Dummy that equals 1 if a US patent, and 0 otherwise	0.26	0.44	0.32	0.47
Japan	Dummy that equals 1 if a Japanese patent, and 0 otherwise	0.16	0.37	0.20	0.40
Renewal	The number of years of patent renewal	10.40	4.59	11.30	4.49
RenewalX	Dummy that equals 1 if the patent is still alive after *X* years, and 0 otherwise. *X* ranges from 4 to 10	–	–	–	–
FIRM1	Dummy taking the value of 1 for medium-sized firms (101–1000 employees), and 0 otherwise	0.13	0.34	0.15	0.35
FIRM2	Dummy taking the value of 1 for small firms (11–100 employees), and 0 otherwise	0.23	0.42	0.26	0.44
FIRM3	Dummy taking the value of 1 for micro companies (2–10 employees), and 0 otherwise	0.16	0.37	0.20	0.40
GOVFIN	Percent of R&D financed by government	7.06	18.6	4.45	13.4
PRIVFIN	Percent of R&D financed by private venture capital	3.14	14.4	3.14	11.3
OTHFIN	Percent of R&D financed by universities/research foundations	2.73	14.4	1.88	14.4
UNIV	Dummy that equals 1 if the patent was created at a university, and 0 otherwise	0.037	0.19	0.021	0.14
KOMPL	Dummy that equals 1 if complementary patents are needed to create a product, and 0 otherwise	0.23	0.42	0.27	0.45
MOREPAT	Dummy taking the value of 1 if the inventors have more similar (competitive) patents, and 0 otherwise	0.41	0.49	0.46	0.50
OWNER	Percent of the patent that is directly or indirectly owned by the inventors	0.72	0.45	0.69	0.46

Table 12 (continued)

Dependent variables	Definition	All observations ($n = 867$)		Commercialized patents ($n = 526$)	
		Mean	Std. dev	Mean	Std. dev
INVNMBR	Number of inventors of the patent	1.34	0.66	1.33	0.65
SEX	Share of inventors who are females	0.023	0.14	0.023	0.14
ETH	Share of inventors with an ethnic background other than Western European or North American	0.030	0.16	0.023	0.15

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Declarations

Conflict of interest The author declares that he has no conflict of interest.

Human and animal rights This article does not contain any studies with human participants or animals performed by the author.

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