Standard essential patents to boost financial returns

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Working Paper Version Original @
Pohlmann, T.; Neuhäusler, P.; Blind, K. (2015): Standard essential patents to boost financial returns, R&D Management, 2015 Jun 1.

Numerous innovative applications build upon standardized technologies. These technologies increasingly incorporate standard essential patents (SEPs). It is crucial to own SEPs in order to achieve and maintain significant market shares. We test the influence of owning SEPs on a firm's financial performance. In our analysis, we use a unique dataset of firms participating in international standard setting organizations (SSOs). Our results indicate a curvilinear (inverse U-shaped) relationship of owning SEPs on a firm's return on assets. The curvilinear relationship suggests that firms should balance their patent portfolio by holding a share of patents, which are essential for standards, and by holding a share of patents on technologies that are not standardized. Our results further show that the effects of owning SEPs depend on the specific SSO as well as on the size of the patent portfolio. Our findings are a first step toward identifying and assessing the financial impact of patents essential to standards. Our empirical tests suggest that companies should pursue a common strategy for patenting and standardization to exploit patented inventions in technology fields where standards matter.

1. Introduction

A firm's innovative capacity is crucial to main taining competitive advantages in knowledge resources, technology advances, price competitions and market positions. In recent years, scholars have increasingly investigated intellectual property rights (IPRs) and their influence on firms' financial performance (Hall et al., 2005; Reitzig and Puranam, 2009). While most of the research studies different indicators of patent quality or value, only few analyses (Rysman and Simcoe, 2008) shed light on the positioning of patents, such as a patent's relevance to a technology standard. A first strand of literature has investigated the effects of participating in standard setting organizations (SSOs) on a firm's market value. Waguespack and Fleming (2009) show that a start-up's participation in standard setting increases the likelihood of a buy-out, yet without analyzing performance measures. Aggarwal et al. (2011)

provide empirical evidence of a positive relationship of a company's participation in standard setting and its returns on stock markets.

The aim of this article is to extend the existing analyses by examining the impact of owning standard essential patents (SEPs) on a company's financial performance, and particularly on its return on assets (ROA). In addition to applying common measurements of patent value, e.g. patent forward citations and patent family size, we focus on information about a patent's essentiality to particular technology standards. SEPs claim an invention that must be used by any company to comply with a technical standard. In the course of SSOs' IPR bylaws, SEPs are subject to mandatory licenses and, by introducing patents to standards, firms agree to commit to licensing these patents under fair, reasonable and non-discriminatory (F/RAND) terms. These 'fair' and 'reasonable' terms must reflect the royalty amount of the technology solution that is the next best alternative (Lerner and Tirole, 2013). By declaring a patent as standard essential, the patent holder must license the patent according to these terms.

Various studies discuss conditions for when to license and when not to license patents. Hill (1992) argues that if firms refuse to license a patent, a competitor's technology may become dominant in the market. In comparison, licensing patents generates income from royalties and promotes a firm's own preferred technology (Lichtenthaler, 2011). However, licensing new technologies to competitors always incorporates the risk of losing control over the dominant technology, which may compromise a firm's competitive advantage. Stresses that revenues generated from patent licensing at the same time reduce revenues from the product markets due to higher competition. Patent licensing may thus have reverse impacts on a firm's financial performance that especially depends on market size and network effects (Lin and Kulatilaka, 2006). Hytönen et al. (2012) find that firms in standard setting only benefit when royalty rates for SEPs are balanced. Firms face the decision to either introduce their patented technology to a standard, thus license out to standard implementing firms, or to retain their technology outside standard setting, upholding the possibility to block competitors and ensure exclusivity. Against this background, we analyze the effect of introducing patents to standards on a firm's financial performance. We collected over 65,000 patent declarations to formal SSOs[1] and informal SSOs[2] from 2000 to 2012 and measured effects by applying multivariate panel analyses. Our results indicate that owning SEPs has a curvilinear (inverted U-shaped) effect on financial returns. We further find that the incremental impact of patents declared to informal SSOs is stronger compared with patents declared to formal SSOs. Additionally, we employ analyses to identify the optimal level of owning SEPs, which is higher for declaring patents for formal standards compared with informal standards. Our results suggest that firms balance their patent portfolio and strategically position patents with regard to different formal or informal SSOs.

The remainder of this paper is structured as follows. In the theoretical section, we discuss the role of patents in standard setting as well as indicators of patent value. We then state our hypotheses, describe the database and define our methodological approach. Subsequently, we present the regression models used to test our hypotheses. We conduct further robustness tests, and offer conclusions in the last section.

2. Literature and theory

The influence of a company's technology assets on its financial performance has been studied extensively. Griliches (1981) and Narin and Noma (1987) were among the first to analyze the influence of certain patent characteristics on a company's sales, profits or market value. In the following, we will discuss several indicators of patent value, as well as the role of patents in standard setting and a patent's essentiality to standards.

2.1. Patents and patent value indicators

Patent applications and patent grants are probably the most important indicators for the technological output of innovation processes within companies (Grupp, 1998). Especially in high-tech areas, such as Information and Communication Technology (ICT) and software, the number of patents can be assumed to exert a positive influence on the financial performance of a company (Hall et al., 2007; Hall and MacGarvie, 2010). Large patent portfolios reflect large research and development (R&D) efforts and thus greater innovative output. This has been shown to influence a firm's performance, in terms of innovativeness and provision of positive market signals and strategic tools to block other market participants' innovative endeavors (Ernst, 2001; Bloom and Van Reenen, 2002; Pohlmann and Opitz, 2013). However, some studies, such as Artz et al. (2010), report a negative association between patents and financial returns and sales growth.

Since patents differ from one another both in economic and technological value, simply counting patent filings could lead to a distorted picture of a company's technology base. Therefore, some additional indicators have been proposed to correct for the quality or value of patents, such as the number of citations a patent receives from subsequent patents (forward citations) (Narin and Noma, 1987; Trajtenberg, 1990; Albert et al., 1991; Blind et al., 2009) or the patent family size to indicate market coverage in terms of distinct offices at which a patent has been filed (Putnam, 1996).

This article extends the analyses on patent counts and patent value indicators to the measurement of the positioning of patents to be essential for standardized technologies.

2.2. SEPs

The goal of standard setting is to achieve consensus on the specifications of a technology (Lyytinen and King, 2006; Markus et al., 2006). This is often crucial to enabling interoperability and unlocking innovation in complex technologies based on various components provided by different suppliers (Chiesa et al., 2002). However, the process of setting a standard can be very costly for participating firms, since standard development requires employee engagement and creates travel expenses for regular meetings and presentations around the world.[3] Firms' benefits from standard setting are diverse, such as the facilitation of technology and products (Weitzel et al., 2006; Peek, 2010), reinforcing user confidence and user acceptance (Brynjolfsson and Kemerer, 1996; Blind et al., 2010), and consequently the emergence of new markets and the growth of existing ones (Blind, 2004). Due to the public good character of a standard, these benefits may accrue in various dimensions and to different degrees for all market participants, not only those that contribute to a standard. While some companies provide their R&D outputs for standard setting, others do not. Introducing patented technology essential for a standard and demanding royalty fees is a practice to recoup a company's R&D investments in standards setting (Farrell and Saloner, 1985), as doing so can generate licensing revenues, offer greater operational freedom and allow for leveraging SEPs as bargaining chips in licensing discussions (Blind et al., 2011).

Essential patents are those a company would necessarily infringe upon when adopting or implementing a technology standard. Standards may incorporate technology components, which are protected by a large number of patents (e.g. UMTS, LTE, Wi-Fi, MPEG, RFID).[4] While standards have to ensure interoperability and should be accessible to all interested stakeholders, granted patents provide their holders with a temporary monopoly right on a technology to exclude others. In the field of standard setting, companies have to declare patents that might affect the standardized technology and agree to license them under F/RAND terms (Layne-Farrar et al., 2007). It is still a common belief that companies who own essential patents are able to exploit their position of technology ownership by demanding excessive royalties when standards are accepted industry wide. Findings from recent literature show that patents increase in value when they are essential for standards (Rysman and Simcoe, 2008; Layne-Farrar and Padilla, 2011). Bekkers et al. (2002) provide evidence that a company's position in a particular network market strongly depends on the number of SEPs. Berger et al. (2012) as well as Caviggioli et al. (2013) identify strategic patent filing behavior of standard setting firms when declaring patents as standard essential.

2.3. Theory and hypotheses

Previous studies have shown that owning patents in ICT markets (Hall et al., 2007; Hall and MacGarvie, 2010) and participating in standard setting (Aggarwal et al., 2011) improve a firm's financial performance. When declaring a patent essential to a standard, patent owning companies have leverage to control whole markets that are based upon the standardized technology. These arguments indicate a positive influence of owning SEPs on a company's financial performance. Contrastingly, there are many arguments that SEPs may decrease financial returns. When companies introduce their patents to a standard, SSOs oblige the patent holder to license the patented technology under F/RAND terms (Layne-Farrar et al., 2007), which caps licensing revenues. Furthermore, cross-licensing in standard setting may lead to homogeneity of knowledge distribution among market participants, which may in return reduce a firm's competitive advantage (Aggarwal et al., 2011) and thus financial returns. Introducing patents to a standard is a firm's individual decision, and firms are not fully able to predict the behavior of other standard setting participants. An increase of SEPs increases the cumulative royalty fee of a standard and simultaneously may decrease a firm's share of the overall licensing income. We thus assume double marginalization effects, where an increase of patent declarations decreases the overall internalization of returns on patents. Additionally, the total number of patent declarations on a specific standard might be so high that the usage of the standard will become expensive and less attractive and thus decrease the demand for the standardized technology (Patterson, 2002). This phenomenon is comparable to the anti-commons problem (Heller and Eisenberg, 1998; Aoki and Schiff, 2008). Another argument is that a larger number of SEPs may incorporate more patents that provide only little merit to the standard or are not even essential to the standard (Bekkers et al., 2011).

Arora and Fosfuri (2003) show that increased licensing profits may decrease the overall profit of the innovator due to decreasing returns on the market level. In order to maintain a competitive advantage, it thus appears to be advantageous for a company to balance the licensing of its patent portfolio (Arora et al., 2013). In the case of standard setting, it may thus be beneficial to introduce a certain share of patents into a standards project while the remaining share of a company's patent portfolio secures differentiation of product designs and complementary applications (Aggarwal et al., 2011). Based on these considerations, we derive the hypothesis that there is a positive incremental effect on a firm's ROA of declaring patents as being essential for standards. While these positive effects may be true for a certain amount of patenting, companies may introduce too many patents into standards projects, which may result in decreasing or even negative effects on ROA. We thus derive our first hypothesis:

H1: Owning SEPs has a curvilinear effect on a company's financial performance, with a slope positive effect at low and moderate levels and a negative incremental effect at very high levels.

Patents may be essential to formal or informal standards. Lerner and Tirole (2006) first introduced the option of SSO selection depending on a concession parameter in relation to technology ownership. An owner of a strong technology will select an SSO aiming to capture much of users' rent via collecting licensing revenues. In the case of a weak technology or the existence of strong alternatives, the technology owner has to make concessions to users, e.g. by signing a royalty free agreement for essential patents incorporated in a standard. In this regard, Layne-Farrar et al. (2014) have made the case that restrictive Intellectual Property (IP) policies of SSOs may discourage companies from joining. Moreover, Chiao et al. (2007) provide empirical evidence that companies may choose to introduce their technologies to standards projects in formal or informal SSOs in view of the highest expected financial returns. In this regard, Leiponen (2008) has shown that participation in formal and informal SSOs often overlaps. Being a member in multiple SSOs allows companies to strategically choose where to introduce patented inventions. Formal and informal SSOs pursue different standardization processes and also differ in their IPR rules (Baron and Pohlmann, 2013). While technology selection in formal standardization aims to be a result of consensus agreement, informal SSOs mostly select technologies by majority voting procedures. Furthermore, formal standardization is open to all interested stakeholders, while informal SSO membership is more exclusive, such as by demanding membership fees. Finally, in formal SSOs, licensing fees for SEPs are restricted by F/RAND commitments, whereas informal SSOs allow less restrictive licensing agreements (Pohlmann, 2014). When considering these institutional differences, we conclude that companies owning strong patents would rather choose informal SSOs, where majority voting and the restricted openness might help to push technology proposals without agreeing to concessions. Furthermore, informal SSOs' less restrictive licensing cap might result in higher royalty fees. We thus predict that the impact of essential patents on a firm's financial performance is stronger when declared to informal SSOs compared with formal SSOs, deriving our second hypothesis:

H2: Owning SEPs declared to informal SSOs has a stronger incremental effect on companies' financial performance compared with owning SEPs declared to formal SSOs.

3. Methodology

3.1. The data

The construction of the dataset for our analyses is based on the DTI scoreboard,[5] which provides an annual ranking of firms according to their R&D expenditures. This initial dataset began in 2001, when a total of 500 companies were listed in the DTI scoreboard. Data on R&D expenditures of these firms from the previous and following years (2000–2007) were added to this dataset in order to construct a firm-level panel. If one of the 500 companies was not listed in the DTI scoreboard in the years before or after 2001, we treated the respective observations as missing. In the case of mergers and acquisitions between companies listed in the DTI scoreboard, the data of the respective companies were added for the entire time period. Such companies were therefore treated as if they were already merged at the beginning of the observation period.[6] Mergers & Acquisitions (M&A) with units not covered by the DTI scoreboard had to be left uncontrolled.[7] Since the DTI scoreboard is a ranking of companies according to their annual R&D expenditures, our sample is biased toward large firms, i.e. large firms are overrepresented in the sample.[8]

In a second step, we added the relevant information on patenting behavior to this dataset. The patent data were extracted from the 'EPO Worldwide Patent Statistical Database' (PATSTAT). The annual sum of patent applications filed at the European Patent Office (EPO) was calculated for each of the firms in the sample. The same was done for the patent value indicators, i.e. for patent forward citations and family size. All patent data from the PATSTAT database are dated by their priorities, i.e. the year of worldwide first filing. We believe that our restriction to analyze EPO patents is sufficient, since over 90% of the essential patents are also filed at the EPO.

To identify the companies listed in the DTI scoreboard in PATSTAT, we employed keyword searches. The keywords included the company names in different spelling variations as well as the names of the subsidiaries[9] held by the parent company with a direct share of at least 25%. This assures comparability of patent data with the financial data from the companies' balance sheets.

In a next step, we added the financial data of the companies that are needed for the construction of our variables – such as total assets or earnings before interest and tax – from Standard & Poor's COMPUSTAT Global and COMPUSTAT North America databases.

We then added information about a patent's essentiality to a standard. In total, we extracted over 65,000 patents declared at formal SSOs such as ISO, IEC, JTC1 – a joint committee of ISO and IEC – CEN/CENELEC, ITU-T, ITU-R, ETSI and IEEE. In addition, we added patents declared at informal SSOs such as IETF, TIA, OASIS, OMA, the Broadband Forum and the MSF Forum. All of the listed SSOs provide public databases about patent number, declaration date and company of declaration.[10] To ensure that each company in our final sample is active in standard setting and is thus able to include its patents in a standard, we only included members of the aforementioned SSOs.[11] With regard to the distribution of companies' presence in the different SSOs, we have found that the patent declarations of the companies in the sample are rather equally distributed across ITU-T, IEEE, ETSI, IEC and JTC-1, whereas ITUR, ISO and CEN/CENELEC are less often frequented.

We then added further information about a company's participation in a patent pool. This is important to account for specific licensing strategies of firms. According to Layne-Farrar and Lerner (2011), pool participation is not automatic and firms only join a pool when it fits their specific licensing business model. Our data includes all pool memberships of 1992–2012. Patent pool administrators state which standards are affected by the patent pool. In combination with our data on patent declarations, we can precisely differentiate between companies that license their patents individually and companies that pool their patents. Patenting relevant for standards increased in the late 1990s, when the licensing of essential patents became a new challenge to standard setting (Simcoe, 2005). Given this rather recent development and to ensure data conformity in our sample, we limited our observations – the declarations – to the years from 2000 to 2007.

Due to these limitations and the fact that we use an unbalanced panel, in which data for some observations in the respective years may be missing, we calculate our models for 817 observations of 134 companies on a yearly basis. All further analyses in the study are based on this final sample.

3.2. *Variables and summary statistics*

In this section, we briefly discuss the variables used in our regression models. The summary statistics of these variables are presented in Table 1 (additional sample statistics on firm distribution in sectors and firm size can be consulted in Tables A1 and A2 in Appendix A). We use the annual ROA per company as a measure of a firm's financial performance.

The number of patent declarations per company and year (both in thousands), related to formal and informal standards, as well as the respective squared terms, are our main explanatory variables.

We further added a variable that captures the number of patent pool memberships per company and year. In patent pools, patent owners pool their patents to agree on a single license for the whole set of patents. Companies may be a member of more than one pool, depending on the standardized technology.

The annual number of patent applications at the EPO (in thousands) per company is a count of a company's issued patents per year. The average number of forward citations is calculated as the number of citations a company's patents receive (in a 4-year time window with regard to the company's filings in a given priority year) divided by the number of patent filings of that priority year, i.e. the citations directly relate to the filings of a given year. The time window assures that all patent filings have the same amount of time to be cited. The average patent family size is the average number of distinct patent offices where a company's patents were filed. The patent family is defined according to the DOCDB family definition of the EPO (Martinez, 2011). This indicator is also calculated per company and year.

Table 1. Summary statistics of the sample variables

Variable	Mean	Std. Dev.	Min	Max	# Obs.	# Firms
ROA (in millions)	0.068	0.081	−0.520	0.387	817	134
# formal SSO declarations (in thousands)	0.048	0.513	0.000	11.413	817	134
# informal SSO declarations (in thousands)	0.001	0.005	0.000	0.065	817	134
# pool licensor seats	0.100	0.002	0.000	0.018	817	134
# patent applications (in thousands)	0.224	0.373	0.001	3.084	817	134
R&D (in m)/sales (in m)	0.074	0.065	0.002	0.708	817	134
Sales (in m)/employees	0.189	0.108	0.042	0.974	817	134
# employees (in thousands)	78.912	88.616	1.030	484.000	817	134
Avg. # FW-Citations	2.391	1.223	1.000	14.861	817	134
Avg. Family Size	5.179	1.671	2.000	14.000	817	134

Note: The summary statistics are only reported for the number of cases that are used in the multivariate regressions.

With respect to potentially confounding firm characteristics, we include further control variables. We include the number of employees (in thousands) to control for size effects. The share of sales (in millions) per employee is introduced as a proxy for how efficiently a firm generates sales. In addition, a company's R&D intensity R&D expenditures (in millions) divided by sales (in millions) enters our models, as this is supposed to affect firm profitability, especially in our sample of relatively large R&D-performing firms. Finally, we use time dummies to account for confounding level effects that occur over the panel period. We should note that industry-specific effects are absent from the model, because they are time invariant and thus drop out by using the fixed effects estimator (compare section 3.4). Industry effects can therefore not be identified.

Since some of the variables employed for the models are correlated with each other (compare Table A3 in Appendix A), we calculated variance inflation factors (VIFs) to test for potential multicollinearity issues that might influence our models (Table A4 in Appendix A). The 'number of patent applications' and the 'number of employees' variables have the highest VIF scores (1.68 and 1.59, respectively) and the mean VIF for the model is 1.25. As a rule of thumb, variables with a VIF value exceeding 10 merit further investigation. Hence, we find no multicollinearity concerns (O'Brien, 2007).

3.3. The model setup

In order to test our hypotheses, we regress a firm's ROA on its SEP portfolio declared within formal and informal standards organizations, including squared terms to test for non-linearity, the number of pool memberships, the number of patent filings, the patent value indicators as well as other innovation and financial performance-related control variables, i.e. sales per employee, R&D intensity as well as company size. All variables enter the model per company and year observation. In sum, we seek to isolate the correlations between formal and informal SEP declarations and a firm's ROA.[12] Our final model can be described as follows:

$$\begin{aligned} ROA_{it} = {} & \alpha_{1it} PDC_{it} + \alpha_{2it} PDC^2_{it} + \alpha_{3it} CDC_{it} \\ & + \alpha_{4it} CDC^2_{it} + \alpha_{5it} PLS_{it} + \alpha_{6it} PAT_{it} \\ & + \alpha_{7it} CIT_{it} + \alpha_{8it} FAM_{it} + x'_{it}\beta_{it} + c_i + u_{it} \end{aligned} \qquad (1)$$

with $i = 1, \ldots, n$ $t = 1, \ldots T$ where ROA_{it} denotes the ROA of unit i in period t, PDC_{it} and CDC_{it} are patent declarations to formal and informal SSOs, respectively; PLS_{it} is the number of pool membership seats; PAT_{it} is the total number of patent applications; CIT_{it} and FAM_{it} are the average number of total forward citations to a company's patent portfolio and the average family size of the respective patent portfolio. Furthermore, x_{it} is a vector of control variables, c_i is a company-specific effect and u_{it} is the idiosyncratic errors.

3.4. Estimation method

Since the data used for our analysis are in the form of a company-level panel, the econometric specifications have to take account of the peculiarities of this data structure. Our model can be estimated by a fixed effects regression model, i.e. a within estimator, that eliminates the fixed effects by centering each variable on its individual-specific mean, taking into account potentially endogenous individual effects. To control for non-constancy in the residual variance of the variables in our regression model, we employ cluster robust standard errors by company, which are heteroscedasticity consistent (White, 1980).

If models are subject to unobserved heterogeneity, which is correlated with the explanatory variables, simple pooled Ordinary Last Squares (OLS) estimators are asymptotically biased. To account for this problem, linear panel data models are used in order to eliminate time-constant unobserved heterogeneity. To decide between fixed or random effects, we additionally employed a Hausman test that showed that the random-effects assumption (that explanatory variables are uncorrelated with company-specific effects) is violated. This would lead to systematically biased coefficients as well as standard errors. Therefore, only a fixed-effects estimator results in unbiased estimates. In particular, the linear panel data model is as follows:

$$y_{it} = x_{it}\beta + c_i + u_{it} \qquad i = 1,\dots, n \quad t = 1,\dots T \qquad (2)$$

where y_{it} is the explained variable of unit i in period t, x_{it} is a vector of explanatory variables, β is a coefficient vector, c_i is a company-specific effect and u_{it} is the idiosyncratic errors. In order to test the influence of each of the individual explanatory variables on ROA, we calculate several models and add the respective variables gradually.

4. Empirical results

4.1. *Model outcome*

The results of our multivariate analysis are presented in Table 2. As stated in section 3, we estimated several models and added the respective variables gradually up to our final model that corresponds to Equation (1).

In our models (M1–M6), we are able to show that SEPs declared to standards issued by formal and informal SSOs, ceteris paribus, have a curvilinear relationship (inverted U-shape) with a firm's ROA. We are therefore able to confirm our first hypothesis, H1 – that companies' SEP ownership significantly increases their ROA up to a certain point. We further confirm that there is a maximum in this relation, which is modeled by the negative squared effects of formal and informal SEP declarations. From this maximum point onwards, the incremental effect of owning SEPs on ROA becomes negative. These results support the assumption of an overdeclaration effect, where declaring a very large number of SEPs decreases firm performance from a certain point onwards.

Our empirical findings further confirm our second hypothesis, H2. The incremental impact of owning SEPs declared to informal standards has a stronger marginal effect on companies' financial performance compared with SEPs declared to formal standards.

The effects of our explanatory variables also hold when adding the number of pool licensor seats of a company as a control variable to our models. However, our results show that the selection of this specific licensing strategy[13] does not influence a firm's financial performance. Furthermore, firms' licensing strategies are also subject to different IP policies of SSOs. Our differentiation into formal and informal patent declarations might thus already capture the differences in licensing regimes. Similar results can be derived for the rest of our control variables, which are added in M5 and M6. When controlling for size effects, increased R&D intensity, the total number of patent applications and the value of the patent portfolio, our results remain consistently significant. However, it can be shown that the firm-specific as well as the innovation-related indicators strongly increase the explanatory power of the models, implying that the chosen indicators also affect firm performance. The statistical tests show that R&D intensity has a significant negative influence on ROA. This negative effect can be explained by the characteristics of our variable. R&D investments are costs which might pay off only several years after the investment. For example, a company invests in new innovative processes or technologies. Yet, it is unsure whether or not these investments will be successful and contribute to a company's performance. Therefore, at least from a short-term point of view, R&D investments are first of all costs which consequently have a negative effect on the ROA.

Our variable of labor productivity (sales by employees) has a significantly positive effect on ROA. As for the number of patent applications, on the other hand, no significant coefficients can be observed. This result once more points to the fact that it is not sufficient to account for a company's technological performance by solely measuring the number of patent filings. We therefore include patent value indicators in our final model (M6). However, in our estimation, the average patent family size has no effect on ROA and the average number of forward citations even shows a negative impact on our explained variable, although this effect is rather small. There has been evidence in the literature stating that patents, which are essential to a standard, have a higher number of forward citations (Rysman and Simcoe, 2008; Layne-Farrar and Padilla, 2011). In our sample, however, we find that patent forward citations are correlated with neither formal nor informal declarations, similar to the results of Berger et al. (2012) and Caviggioli et al. (2013). An explanation for the negative coefficient in the case of the forward

Table 2. Results of the fixed-effects panel regression models

dV: ROA	M1		M2		M3		M4		M5		M6	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
# formal SSO declarations	0.019***	0.007			0.019***	0.006	0.019***	0.006	0.027***	0.009	0.028***	0.009
# formal SSO declarations sq[1]	−0.002***	0.001			−0.002***	0.001	−0.002***	0.001	−0.002***	0.001	−0.002***	0.001
# informal SSO declarations			2.031	1.308	2.050	1.271	1.870	1.288	2.710**	1.194	2.572**	1.177
# informal SSO declarations sq			−0.041*	0.025	−0.041*	0.023	−0.038*	0.022	−0.050**	0.023	−0.046**	0.023
# pool licensor seats							2.115	2.358	0.280	2.229	0.164	2.322
# patent applications									0.006	0.016	0.004	0.016
R&D/sales									−0.725***	0.124	−0.728***	0.124
Sales/employees									0.138*	0.071	0.142**	0.068
# employees[1]									0.044	0.203	0.054	0.200
Avg. # FW-Citations											−0.005*	0.002
Avg. Family Size											0.003	0.003
Constant	0.084***	0.007	0.082***	0.007	0.082***	0.007	0.079***	0.008	0.107***	0.033	0.102***	0.032
Time Dummies	YES		YES		YES		YES		YES		YES	
Number of companies	134		134		134		134		134		134	
Observations	817		817		817		817		817		817	
R^2 within	0.169		0.17		0.172		0.173		0.322		0.328	
F	7.735		6.733		5.987		5.59		10.014		9.284	

Significance level: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.

Note: [1]Coefficient multiplied by 1,000 to make effects visible. The number of observations in each model was adjusted to the model with the fewest observations (M6) in order to conserve comparability of the effects over all models.

citations in our model might be that a positive effect of forward citations might unfold over time. This explanation is somewhat backed by the result that the coefficient becomes insignificant when replacing the forward citations variable by its 1-year lagged version. In addition, when specifying the forward citations indicator in relation to the industry average of forward citations, we find a non-significant positive coefficient, implying that a more fine-grained specification of this variable might yield different results. However, a detailed analysis of this effect goes beyond the scope of the current study and has to remain a question for further research.

In sum, our multivariate results support our predictions related to the effect of SEPs and illustrate a curvilinear influence on a firm's ROA. However, our analysis has not yet provided specific information on an optimal level of declaration. We therefore multiply the coefficients of our final model (M6) with SEPs declared to formal and informal SSOs and plot the distribution over the normalized number of total SEPs per firm (Figure 1). Our empirical models have shown that the incremental effects of SEPs are higher if declared to standards issued by informal SSOs compared with those declared to formal SSOs. However, Figure 1 illustrates that the optimal level of

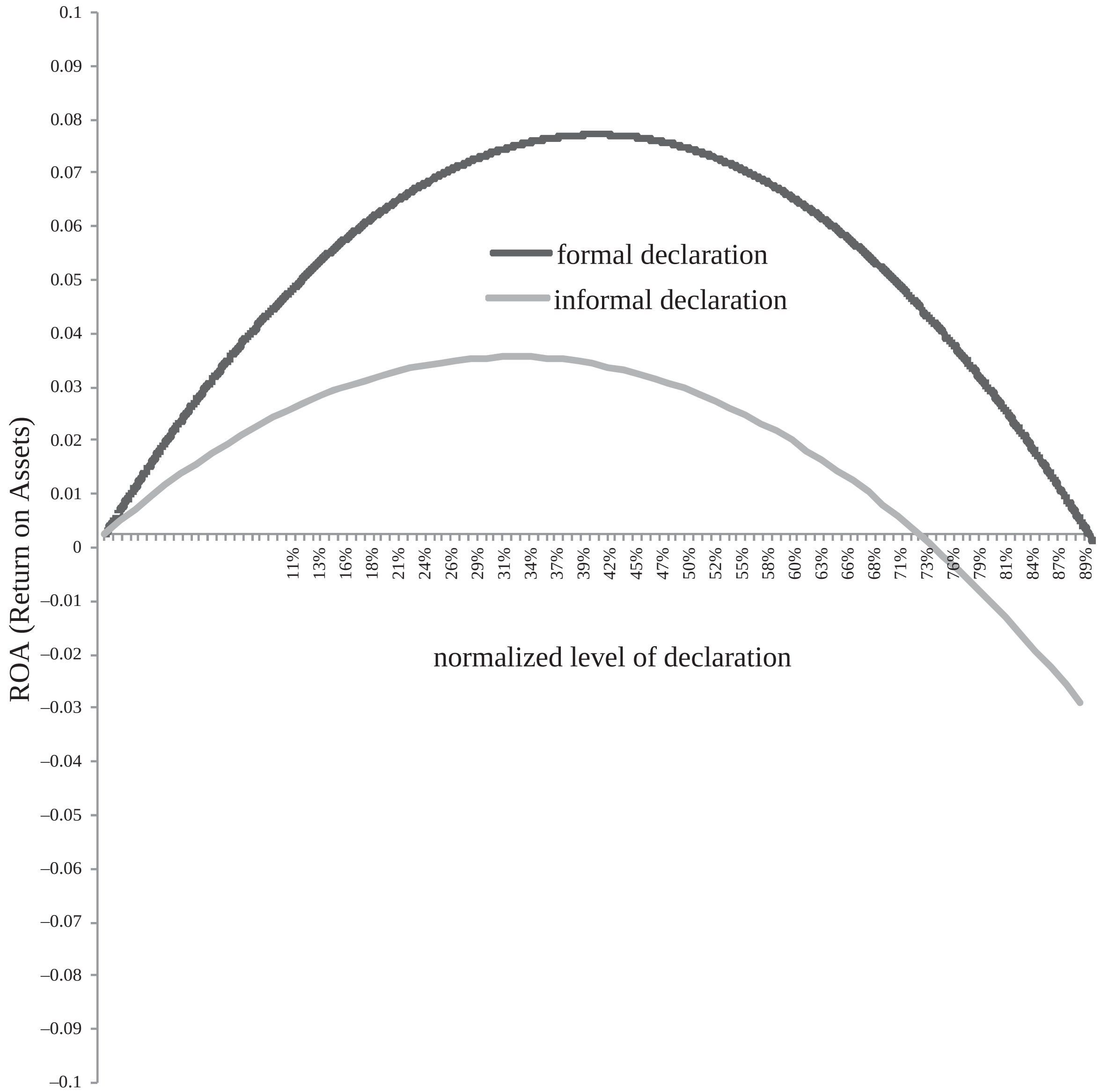

Figure 1. Coefficients of M6 multiplied by the normalized number of formal standard setting organization (SSO) and informal SSO declarations.

SEP declaration is higher for formal SSOs, meaning that firms are able to introduce a higher number of patents to formal standards until the incremental effect on ROA turns negative.

The analysis of an optimal level of patent declarations should be interpreted cautiously, indicating general tendencies rather than precise effects and benchmarks. Firms participate in very specialized standard working groups, where they work on technical problems that may differ strongly among SSOs.

4.2. Robustness checks

We perform additional robustness checks to test whether our results remain robust over different model specifications (Table 3). All of the robustness checks are performed on the basis of the final model specification (M6).

Our first concern regarding our model is that the dependent variable ROA does not hold the normality assumption. To stabilize the variance of our dependent variable, we performed a z-standardization, a log-transformation and a Cox-transformation of the ROA variable and re-ran our model with each of the transformed variables. All three models with standardized dependent variables show similar effects of the explanatory variables. Coefficients for formal and informal declarations and the squared terms show slightly smaller values when the Cox-transformed ROA is used. However, the coefficients do not change signs and remain significant at the 1% and at the 5% level, respectively. In the case of the z-standardized ROA variable, the strength of the effects even increases and all coefficients show the same significance levels as in the original specification. For the log-transformed ROA, the coefficients become stronger, but slightly less significant than in the original model. Except for the squared effect for the number of informal declarations, however, the coefficients remain significant at the 5% level.

We also z-standardized and log-transformed the declaration variables and used them as explanatory variables in our models to correct for the skewness in the count of formal and informal declarations.[14] As for the z-standardized explanatory variables, the values of the coefficients for formal and informal declarations become smaller but remain significant. As for the log-transformed explanatory variables, we find increasing values of the coefficients for each of the variables and also a slight decrease in significance compared with the original specification. However, all variables remain significant at least at the 10% level.

A second approach towards testing the robustness of our results is to replace our explained variable ROA by different, yet similar, dependent variables that account for a firm's financial performance. In a first step, we replaced the earnings before interest and tax in the ROA calculation by earnings before interest, taxes, depreciation and amortization. With the help of this specification, we are able to test if potential effects of amortization or depreciation,

Table 3. Coefficients of the explanatory variables for the modified models

	# formal SSO declarations	# formal SSO declarations sq[1]	# informal SSO declarations	# informal SSO declarations sq
dV: ROA (Original Model (M6))	0.028***	−0.002***	2.572**	−0.046**
dV: Cox-transformed ROA	0.019***	−0.002***	1.910**	−0.037**
dV: z-standardized ROA	0.313***	−0.028***	28.905**	−0.522**
dV: Log-transformed ROA	0.029***	−0.003**	2.441**	−0.04
dV: ROA, z-standardized declaration variables	0.004***	−0.062***	0.004**	−0.0001**
dV: ROA, Log-transformed declaration variables	0.083**	−30.265*	2.631**	−46.996*
dV: ROA, EBITDA instead of EBIT used for ROA calculation	0.020**	−0.002**	1.431	−0.032*
dV: ROIC	0.039**	−0.004**	3.655*	−0.062
dV: EBIT as a share of sales	0.064***	−0.005***	5.586**	−-0.097**
dV: ROA, lagged control variables[2]	0.028***	−0.002***	2.651**	−0.048**
dV: ROA, stocks of declaration variables and patent applications	0.003	−0.327	3.027*	−26.121*
dV: ROA, linear effect of SEPs (no squared terms)	0.003	–	0.346	–

Significance level: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.

Note: [1]Coefficient multiplied by 1,000 to make effects visible. [2]These measures could only be calculated with a reduced number of cases due to the construction of the dependent variable or the lagged specifications of the explanatory variables. Only the coefficients for the relevant explanatory variables are shown. The full results of the models can be consulted in Table A5 in the annex.

which are implicitly represented in our original ROA specification, are responsible for the effects we find for patent declarations related to formal and informal standards. Second, we created a variable for the return on invested capital that is calculated as the share of earnings before interest and tax divided by the invested capital of a company in a given year, and used this as a dependent variable in our model. Third, we calculated earnings before interest and tax divided by sales, which is closely related to the net profit of a firm per year. As we can see in Table 3, our results remain rather stable also in different specifications of the dependent variable.

In a third approach, we specify the patent-related control variables in the model – namely the number of patent applications, the average number of forward citations and the average family size – with a 1-year lag to account for a possible timely delayed effect on ROA that might mitigate the results found for our main explanatory variables. However, this is not the case. The coefficients remain robust and significant at least at the 5% level. When including stocks for the number of formal and informal patent declarations and the number of patent filings for the last 5 years – the stocks were calculated via a perpetual inventory approach based on an annual deflation factor of 15% (compare Hall et al., 2005) – instead of annual values, the coefficients for formal declarations loose significance, while the results for informal declarations remain robust. Compared with the model of Hall et al. (2005), however, our patent stock variable is not significantly correlated to the performance measure. This might be due to the specification of our variable, i.e. we simply use the stock of a company's patent filings and do not relate it to its input in the form of R&D as Hall et al. (2005) did. In addition, Hall et al. (2005) use Tobin's q instead of ROA as a response variable. Another part of the explanation might be that our model includes several innovation-related variables (i.e. patent filings, formal and informal declarations, R&D intensity and patent value indicators) that are partially interrelated despite the relatively low correlations between our variables (compare Table A3). Including the variable specification of Hall et al. (2005) and dropping the R&D intensity measure reveals a highly positive significant effect of the variable on ROA, while the results of the declaration variables are comparable to the model including the more simple stock of patent filings.

Our final concern regarding the model is associated with the assumption of an inverse U-shaped relationship between patent declarations in formal and informal SSOs. We therefore re-ran our model excluding the squared terms for formal and informal declarations to find out whether either one of these variables has a significant linear effect on ROA. In both cases, we find positive but non-significant coefficients. We conclude that our assumption of a non-linear relationship between formal and informal patent declarations and ROA is better able to capture the interrelations between the variables.

5. Discussion of the results

Our results provide evidence that the financial performance of companies active in technology-related markets is not only connected to their innovative capabilities and resources, but also further depends on the strategic positioning of their patent portfolio. In particular, we show that firms strategically incorporate their patents into technology standards to improve their financial performance.

Declaring patents as essential for standards requires licensing these patents under F/RAND terms. In general, licensing patents to other market participants positively influences a firm's revenues through channels of royalty or market income by promoting a preferred technology. However, licensing too many patents may decrease market profits beyond licensing profits with an overall negative incremental effect on a firm's revenue streams (Hill, 1992; Arora and Fosfuri, 2003; Apolemas, 2007). Against this background, our results confirm a curvilinear relationship of owning SEPs and financial performance. Declaring patents to be standard essential increases a firm's financial performance up to a certain optimal level, after which the positive effect decreases. Our findings suggest an optimal balancing of a firm's standard-related patent portfolio.

Standard setting allows firms to freely choose their preferred forum for standardization. Given this, firms would always select SSOs where their technology contributions generate the highest returns (Lerner and Tirole, 2006; Layne-Farrar et al., 2014). Our estimations confirm a stronger incremental positive effect of patent declarations within informal SSOs compared with formal SSOs. However, while the incremental effect for formal SSOs is lower, our analysis indicates a higher optimal level of financial returns for declaring patents to formal standards. Our results suggest that firms should carefully choose which patent to declare to which type of SSO, depending on the size and value of its individual patent portfolio.

Our analysis faces various limitations. A crucial feature of our data is that the unit of observation is at the company and not the technology level. It can be argued that the technology or standard level analysis might be more suitable in capturing the heterogeneity of different standard projects. However, we are not able to conduct financial performance analyses at the standard level, which would require data about the turnover or profits derived from products or licensing revenues based on specific standards. Licensing agreements are based on numerous products, technologies and standards including numerous patents, which would require a very complex dataset. Besides these insolvable data restrictions, we assume a certain extent of homogeneity of technology, i.e. patents and standards in the companies' patent portfolios or at least a homogeneous distribution of relevant characteristics among companies. The second shortcoming of our analysis is the fact that we only use the ROA as a measure of financial performance, including some related performance indicators in the robustness check, and no further performance measures where effects might differ. Third, our sample is limited to companies listed in the DTI scoreboard, i.e. not all companies that declare patents as standard essential are included, which limits the generalizability of our results. We also do not take into account mergers or acquisitions of companies over the observation period, such that the set of a company's subsidiaries remains constant over time. Finally, our model does not allow including industry-specific effects, although the use of standards and SEPs can be assumed to vary across sectors and technology domains. Consequently, we cannot identify whether our effects might be different in one sector or another. An analysis of industry-specific effects, however, would have gone beyond the scope of the current study and has to remain an avenue for further research.

Despite these limitations, our analysis represents a first step toward identifying and assessing the financial impact of patents essential for standards. Our findings may help IP and standardization managers to improve their decision-making processes. In particular, we suggest that firms should have a common strategy for patenting and standard setting activities. Firms should carefully organize their portfolios to identify patented inventions that could be incorporated in standards. While most organizations' patent departments and standards departments work separately,[15] our results strongly suggest combing the two departments to follow a common approach for patenting and standardization activities. Also, based on our findings, firms should consider the value of their patented inventions when choosing a venue for standard setting.

Essential patents claim inventions that must be used by any company to comply with an industry-wide accepted standard. From a legal perspective, essential patents are therefore valuable bargaining chips in cross-licensing negotiations or even legal disputes. One main reason for the increasing litigation on SEPs is the increasing commercial value of such patents (Blind and Pohlmann, 2013). Our results confirm that firm benefits from using SEPs outweigh the coincidental loss of exclusivity.

Our findings may further help SSOs and regulatory bodies to perceive the financial relevance of patents in standardization processes, improving their understanding of increasing litigation related to SEPs. While our findings may confirm a correlation of essential patent ownership and a firm's financial performance, legal disputes – especially when connected to identifying reasonable royalty rates – may raise even more complex questions requiring further consideration of competition, contract and patent law regulations. However, our analysis shows that SSOs should be aware that participants in standard setting may have vested interests in certain technologies which may result in introducing their preferred patented technologies to be incorporated in standards. These patented technologies might not always be the best solution for the standard setting project.

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Notes

1. ISO (International Organization for Standardization), IEC (International Electrotechnical Commission), JTC1 – a joint committee of ISO and IEC, CEN/CENELEC (Comité Européen de Normalisation), ITU-T, ITU-R (International Telecommunication Union), ETSI (European Telecommunications Standards Institute) and IEEE (Institute of Electrical and Electronics Engineers).
2. IETF (Internet Engineering Task Force), TIA (Telecommunications Industry Association), OASIS (Advancing open standards for the information society), OMA (Open Mobile Alliance), the Broadband Forum and the MSF Forum (Multiservice Switching Forum).
3. Chiao et al. (2007) interviewed practitioners in standard setting and retrieved information on IBM, which spent more than 500 million USD on standard setting expenses, representing almost 8.5% of their R&D budget in 2005.
4. UMTS (Universal Mobile Telecommunications System), LTE (Long Term Evolution), Wi-Fi (trademark name of the Wi-Fi Alliance, The Standard for Wireless Fidelity), MPEG (Moving Picture Experts Group).
5. The DTI-Scoreboard is an annual ranking of firms according to their R&D expenditures. It was initially set-up by the UK government's Department of Trade and Industry. The latest version of the Scoreboard has been published by the Department for Business, Innovation and Skills (BIS). However, they reinstated their service for the scoreboard in 2012. Earlier versions that have been used to create the dataset for this analyses can be accessed at the UK Government National Archive: http://www.webarchive.nationalarchives.gov.uk/20101208170217/http://www.innovation.gov.uk/rd_scoreboard/?p=31
6. We chose this approach to preserve comparability over time, as the separation of the individual company information is no longer possible after a merger (compare Frietsch, 2006).
7. In any case, since it contains the most important R&D performers, enterprises not listed should be smaller and distortions should be limited.
8. An overview of the size distribution in terms of employees is located in Table A1 in the annex.
9. Information about the names of the relevant subsidiaries by company was added from the LexisNexis (http://www.lexisnexis.com) and Creditreform Amadeus (http://www.creditreform.com) databases. The sets of subsidiaries per firm do not vary with respect to time, i.e. for each company, the subsidiaries were collected at one specific point in time. The companies plus their subsidiaries were considered as being static over the entire observation period.
10. Examples of SEP declaration lists for ISO standards can be found at http://www.iso.org/patents or for ETSI standards at: http://www.ipr.etsi.org/ or for IETF patents at: https://www.datatracker.ietf.org/ipr/search/
11. We employed membership information from the SSO's web pages. If the membership information was not at hand, we added information of attendee lists of conferences organized by the respective SSOs.
12. We have experimented with this specification and also employed a generalized method-of-moments (GMM) dynamic panel estimator for the first difference transformation in order to control for potential autoregressive effects, i.e. the ROA of a company in a given year might be significantly influenced by the company's ROA from the previous year. The results of the model have shown to be very similar to the more simple specification applied here, however, as tests have shown, with weak instruments. We have therefore decided to stick with the more simple specification. In

addition, since the cost to declare a patent to be essential is close to zero, an influence of a company's ROA on the patent declarations is unlikely from the cost perspective, implying that endogeneity should not be an issue here.

13. Compared with other patent owning firms, pool members do not individually license their standard essential patents. Patent pool memberships indicate a certain licensing strategy of a firm (Layne-Farrar and Lerner, 2011).
14. Besides skewness, both variables also suffer from zero-inflation, i.e. there is a large number of observations with zero patent declarations ($N = 641$ in the case of formal declarations and $N = 734$ for informal declarations). We thus re-ran the models including a dummy variable indicating whether or not an observation belongs to the group of 'zero declarations' for formal and informal declarations. The coefficients of the dummy variables were not significant and the coefficients of the explanatory variables only changed slightly, which is why we conclude that zero-inflation in the explanatory variables does not affect our results. In addition, a model excluding outliers, i.e. the three observations with the largest number of formal declarations, did not change the basic picture.
15. A survey of German manufacturers active in patenting and standardization revealed that most of these companies have separate departments that deal with patenting and standardization issues (Rauber and Blind, 2013). In this regard, the head of standardization of a German car manufacturer stated that the standards department and the patent department did not communicate for years and that they are in course of changing this situation. Other companies e.g. Siemens have restructured their departments in recent years and created a *'Corporate Intellectual Property – Licensing & Transactions'* division, which coordinates standardization and patenting strategies.

Tim Pohlmann is a research associate in economics of innovation at the 'Law and Economics of Patents Group' CERNA, MINES ParisTech and a research fellow at the Berlin Institute of Technology. Dr. Pohlmann is founder and managing director of the patent analytics company IPlytics that has developed a software as a service tool to analyze market developments, technology trends and a company's competitive position for patenting and standardization. The analytical tool IPlytics Platform integrates patent valuations and a mapping of patents to technology standards and products. IPlytics Platform helps companies making the right R&D investment decisions by providing actionable and trustworthy insights on relevant IP assets. Dr. Pohlmann's expertise covers the empirical analysis of patent strategies, patent landscaping, the interplay of patents and standards, the pooling of patents, technology licensing, patent trolls and standard setting. Dr. Tim Pohlmann earned his doctoral degree with the highest distinctions from the Berlin Institute of Technology with a dissertation on patenting and coordination in Information and Communication Technology (ICT) standardization. During the last years Dr. Tim Pohlmann has been actively involved in preparing studies for the European Commission, the World Intellectual Property Organization (WIPO), the German 'Expertenkommission Forschung und Innovation' and the German Federal Government on economic effects of patents, patent licensing, patent markets, technology trends and the interplay of IPR and standards.

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Knut Blind studied economics, political science and psychology at Freiburg University. In the course of his studies he spent one year at Brock University (Canada), where he was awarded a BA. Finally, he took his Diploma in Economics and later his doctoral degree at Freiburg University. Between 1996 and 2010 he joined the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe, Germany, as a senior researcher and at last as head of the Competence Center 'Regulation and Innovation'. In April 2006, Knut Blind was appointed Professor of Innovation Economics at the Faculty of Economics and Management at the Technische Universität Berlin. Since May 2008 he holds also the endowed chair of standardisation at the Rotterdam School of Management of the Erasmus University. From April 2010 he is responsible for innovation and technology transfer at the Fraunhofer Institute of Open Communication Systems FOKUS in Berlin. Since 2008, he is chairman of the CEN-CENELEC Working Group Standardisation, Innovation and Research STAIR. In 2012, he initiated both the Berlin Innovation Panel and the German Standardization Panel. Besides numerous articles on standardization he published about patents and further innovation aspects in refereed journals.

Appendix

Table A1. Distribution of the sample: company size

Number of employees	Obs.	%	Firms	%
0–9,999	99	12.12	25	18.66
10,000–49,999	323	39.53	63	47.01
50,000–99,999	183	22.4	39	29.1
100,000 and more	212	25.95	39	29.1
Total	817	100	166	123.88

Note: The number of firms exceeds the aforementioned 134 firms (100%) in total because the number of employees changes each time period and might exceed the group thresholds.

Table A2. Distribution of the sample: sector

NAICS Code	NAICS-Sector	Obs.	%	Firms	%	Mean Nr. of Patents	Mean Nr. of Formal SSO Declarations	Mean Nr. of Informal SSO Declarations
221	Utilities (Power, Gas, Water)	13	1.59	2	1.49	8.0	0.0	0.0
237	Heavy and Civil Engineering Construction	7	0.86	1	0.75	162.1	0.0	0.0
311	Food Manufacturing	7	0.86	1	0.75	15.3	0.0	0.0
322	Paper Manufacturing	15	1.84	2	1.49	263.6	0.0	0.0
325	Chemical Manufacturing	64	7.83	11	8.21	99.2	0.0	0.0
326	Plastics and Rubber Products Manufacturing	6	0.73	1	0.75	133.5	0.0	0.0
331	Primary Metal Manufacturing	18	2.2	4	2.99	35.8	0.0	0.0
333	Machinery Manufacturing	44	5.39	7	5.22	148.6	0.1	0.0
334	Computer and Electronic Product Manufacturing	346	42.35	57	42.54	228.3	102.4	1.8
335	Electrical Equipment, Appliance, and Component Manufacturing	36	4.41	7	5.22	159.4	5.0	0.1
336	Transportation Equipment Manufacturing	138	16.89	20	14.93	294.5	0.0	0.0
339	Miscellaneous Manufacturing	11	1.35	2	1.49	16.4	0.0	0.0
511	Publishing Industries (except Internet)	23	2.82	4	2.99	130.6	0.7	1.8
517	Telecommunications	42	5.14	8	5.97	145.6	21.5	0.1
541	Professional, Scientific, and Technical Services	26	3.18	4	2.99	288.5	33.3	1.8
999	Missing	21	2.57	3	2.24	1018.1	89.0	0.3
Total		817	100	134	100			

Table A3. Pairwise correlation matrix of sample variables

	1	2	3	4	5	6	7	8	9
1. ROA	1								
2. # formal SSO declarations	0.05	1							
3. # informal SSO declarations	0.05	0.21***	1						
4. # pool licensor seats	−0.01	0.02	0.03	1					
5. # patent applications	−0.03	0.11***	0.09***	0.41***	1				
6. R&D/sales	−0.15***	0.10***	0.24***	−0.07*	0.05	1			
7. Sales/employees	0.09**	0.06*	0.14***	−0.01	−0.04	0.01	1		
8. # employees	−0.06*	0.00	−0.01	0.27***	0.53***	−0.25***	−0.09***	1	
9. Avg. # FW-Citations	−0.06*	−0.01	0.00	−0.12***	0.01	0.04	0.02	−0.07**	1
10. Avg. family size	0.13***	0.04	−0.03	−0.09**	−0.04	−0.03	−0.01	−0.10***	0.35***

Significance level: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.
Note: The correlation analysis is based on the number of cases that are used in the multivariate regressions.

Table A4. Variance inflation factors (VIFs) for the sample variables

Variable	VIF	SQRT VIF	Tolerance	R^2
# formal SSO declarations	1.07	1.03	0.938	0.062
# informal SSO declarations	1.13	1.06	0.887	0.113
# pool licensor seats	1.24	1.11	0.805	0.195
# patent applications	1.68	1.30	0.595	0.405
R&D/sales	1.20	1.10	0.833	0.167
Sales/employees	1.03	1.02	0.968	0.032
# employees	1.59	1.26	0.629	0.371
Avg. # FW-citations	1.16	1.08	0.861	0.139
Avg. family size	1.16	1.07	0.865	0.135
Mean VIF	1.25			

Table A5. Coefficients of the explanatory variables for the modified models (part 1)

	dV: ROA (Original Model (M6))		dV: Cox-transformed ROA		dV: z-standardized ROA		dV: Log-transformed ROA		dV: ROA, z-standardized declaration variables		dV: ROA, Log-transformed declaration variables	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
# formal SSO declarations	0.028***	0.009	0.019***	0.006	0.313***	0.103	0.029***	0.011	0.004***	0.001	0.083**	0.035
# formal SSO declarations sq[1]	−0.002***	0.001	−0.002***	0.001	−0.028***	0.009	−0.003**	0.001	−0.062***	0.021	−30.265*	15.771
# informal SSO declarations	2.572**	1.177	1.910**	0.902	28.905**	13.226	2.441**	1.123	0.004**	0.002	2.631**	1.212
# informal SSO declarations sq	−0.046**	0.023	−0.037**	0.016	−0.522**	0.259	−0.040	0.025	0.000**	0.000	−46.996*	25.477
# pool licensor seats	0.164	2.322	0.458	1.658	1.845	26.088	−0.374	2.330	0.164	2.321	0.031	2.224
# patent applications	0.004	0.016	0.003	0.012	0.041	0.184	0.002	0.016	0.004	0.016	0.002	0.017
R&D/sales	−0.728***	0.124	−0.471***	0.097	−8.185***	1.398	−0.787***	0.114	−0.728***	0.124	−0.729***	0.125
Sales/employees	0.142**	0.068	0.123***	0.047	1.598**	0.766	0.109	0.074	0.142**	0.068	0.146**	0.067
# employees[1]	0.054	0.200	0.066	0.134	0.603	2.249	0.010	0.215	0.054	0.200	0.063	0.194
Avg. # FW-Citations	−0.005*	0.002	−0.003**	0.002	−0.053*	0.028	−0.005*	0.003	−0.005*	0.002	−0.005*	0.002
Avg. Family Size	0.003	0.003	0.002	0.002	0.030	0.029	0.003	0.003	0.003	0.003	0.003	0.003
Constant	0.102***	0.032	−0.344***	0.022	0.219	0.362	0.109***	0.035	0.102***	0.032	0.100***	0.032
Time Dummies	YES		YES		YES		YES		YES		YES	
Number of companies	134		134		134		134		134		134	
Observations	817		817		817		817		817		817	
R^2 within	0.328		0.336		0.328		0.299		0.328		0.330	
F	9.28		9.39		9.28		9.07		9.26		8.61	

Table A5. (Cont.). Coefficients of the explanatory variables for the modified models (part 2)

	dV: ROA, EBITDA instead of EBIT used for ROA calculation		*dV: ROIC*		*dV: EBIT as a share of sales*		dV: ROA, lagged control variables[2]		dV: ROA, stocks of declaration variables and patent applications		dV: ROA, linear effect of SEPs (no squared terms)	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
# formal SSO declarations	0.020**	0.009	0.039**	0.016	0.064***	0.015	0.028***	0.009	0.004	0.013	0.003	0.002
# formal SSO declarations sq[1]	−0.002**	0.001	−0.004**	0.002	−0.005***	0.001	−0.002***	0.001	−0.327	1.218	–	–
# informal SSO declarations	1.431	1.127	3.655*	1.929	5.586**	2.246	2.651**	1.226	3.027*	1.826	0.346	1.055
# informal SSO declarations sq	−0.032*	0.020	−0.062	0.042	−0.097**	0.041	−0.048**	0.023	−26.121*	14.433	–	–
# pool licensor seats	0.364	2.596	4.003	4.339	−6.033	4.125	0.124	2.274	−1.077	2.527	0.717	2.610
# patent applications	0.013	0.017	0.023	0.029	0.034	0.023	−0.006	0.020	0.009	0.016	0.007	0.016
R&D/sales	−0.657***	0.092	−0.949***	0.202	−2.587***	0.641	−0.717***	0.122	-0.718***	0.120	−0.718***	0.120
Sales/employees	0.194***	0.061	0.231*	0.133	−0.002	0.218	0.140*	0.074	0.149**	0.062	0.144**	0.068
# employees[1]	0.230	0.169	−0.050	0.342	−0.120	0.335	0.053	0.202	−0.006	0.208	0.015	0.208
Avg. # FW-Citations	−0.005**	0.002	−0.008*	0.004	−0.006	0.005	−0.002	0.002	−0.004	0.003	−0.005*	0.003
Avg. Family Size	0.003	0.003	0.005	0.004	−0.001	0.005	0.001	0.003	0.003	0.003	0.002	0.003
Constant	0.117***	0.026	0.167***	0.057	0.334***	0.103	0.103***	0.036	0.099***	0.031	0.105***	0.033
Time Dummies	YES		YES		YES		YES		YES		YES	
Number of companies	134		134		134		131		134		134	
Observations	817		817		817		796		817		817	
R^2 within	0.312		0.237		0.4496		0.328		0.338		0.3217	
F	7.75		9.05		7.10		9.23		8.73		10.03	

Significance level: *$P < 0.1$, **$P < 0.05$, ***$P < 0.01$.

Note: [1]Coefficient multiplied by 1,000 to make effects visible. [2]These measures could only be calculated with a reduced number of cases due to the construction of the dependent variable or the lagged specifications of the explanatory variables.