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Abstract

This paper tests a number of hypotheses on the use and effectiveness of patents and trade secrets designed to protect innovation. While previous studies have often considered patents and trade secrets as substitutes for one another, we investigate the complementary role of the two protection methods. We identify protection strategies for single innovation firms and hence overcome the assignment problem of existing empirical studies, i.e. whether firms using both protection methods do so for the same innovation or for different innovations. Employing firm panel data from Germany, we find fairly few differences between the determinants for choosing secrecy and patenting. Single innovators that combine both strategies, 39% of the group, tend to aim at a higher level of innovation and act in a more uncertain technological environment. Firms combining both protection methods yield significantly higher sales with new-to-market innovations. Using only secrecy has slightly stronger positive impacts on firm profitability.

JEL-Classification: O31, O32, O34

Keywords: Patents, Trade Secrets, Performance Impacts, Single Innovation

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1. Introduction

When protecting innovations through patents, firms face a trade-off between disclosing information and obtaining a temporary monopoly for commercialising their inventions (Hall et al., 2014). Since disclosing information may help competitors to develop competing innovations based on a similar technological approach, firms may opt to keep their inventions secret. Theoretical studies show that the choice between patenting and secrecy depends on a variety of factors, including the strength of the protection instrument, the nature of the innovation and the ease of imitation, as well as market structure, firm capabilities and competitor strategies (see Anton and Yao, 2004; Kultti et al., 2006, 2007; Mosel, 2011; Panagopoulos and Park, 2015; Ottoz and Cugno, 2011). Empirical studies frequently find that firms favour secrecy over patenting (Levin et al., 1987; Brouwer and Kleinknecht, 1999; Cohen et al., 2000, 2002; Hall et al., 2013) and consider the former to be more effective than patenting (Arundel, 2001).

While many theoretical studies treat patenting and secrecy as substitutes for one another, firm practices rather suggest that both protection methods are used simultaneously. At a firm level, provided that the two methods are employed for different innovations, this is straightforward. But firms may also choose to mix both strategies at the level of individual innovations by protecting some elements of a technology through patents and keeping others secret (Belleflamme and Bloch, 2014). For example, if innovations involve both codified and tacit knowledge, firms may patent the codified knowledge and keep the tacit knowledge secret (Arora, 1997). Firms may also combine patenting and secrecy in a way that enables them to keep the codified part of an invention secret, whilst maintaining the option of later patenting the invention (Graham, 2004).

In this paper, we empirically analyse the choice of innovating firms to protect their innovations through patenting and/or secrecy, and whether this choice affects innovation success and firm performance. Starting from propositions of theoretical models on the interaction between patenting and secrecy, we investigate a number of factors that are said to influence the use of the two protection mechanisms. A particular focus is placed on preferences for either patents or secrecy, and the factors affecting the choice for a combined protection strategy. Though we are not able to conduct our analysis at the level of individual innovations, we are fortunate to have information about the number of different innovations introduced by a firm. This allows us to investigate the interaction of patenting and secrecy for firms with a single innovation and the performance impacts of the chosen protection strategy.

Similarly to Hall et al. (2013), we explore three types of relationships: (i) the determinants of a firm's decision to protect its innovations through patents, secrecy, or both, (ii) the impact of the chosen protection strategy on innovation performance, and (iii) the profitability implications of the protection strategy. We rely on data from the German innovation survey, a panel survey ("Mannheim Innovation Panel") which constitutes the German contribution to the European Commission's Community Innovation Surveys. We complement this data with information on firms' patent applications from the European Patent Office and the World Intellectual Property Organisation. In contrast to previous empirical studies, we are able to exploit the panel nature of our data base in order to analyse innovation performance impacts for both product and process innovations, and to estimate the effects of patent and trade secrets on firm profitability.

The paper is organised as follows: In the next section we derive hypotheses on determinants of patenting and/or secrecy from theoretical and empirical literature. In Section 3, the data used is described, and descriptive results are presented. In Section 4, we present and discuss the results of our model estimations before providing a conclusion in Section 5.

2. Literature and Hypotheses

In a recent literature survey, Hall et al. (2014) summarised the main results of theoretical and empirical work on firms' choices to protect their innovations through various formal and informal methods. Building upon these results, and considering some more recent literature, we derive six hypotheses on the determinants of patenting and secrecy as protection mechanisms for innovation.

H1. Strength of IP law

An obvious, though often studied determinant of the use of patenting and secrecy as protection methods, is the effectiveness of patent and trade secrets law. The choice of patenting over secrecy is certainly affected by the probability that innovators can effectively protect their innovation from infringement by patent law. On the other hand, a strong trade secrets law encourages firms to rely on this protection method. In a theoretical model, Kultti et al. (2007) demonstrate that an effective patent system stimulates patenting particularly where firms expect that other firms will develop similar inventions. Secrecy is preferred only if innovators can be quite sure that they are the sole innovators. Denicolò and Franzoni (2004) consider the length of patent protection and prior-user rights. Longer patent life implies a higher propensity to patent for first inventors, while prior-user rights would foster innovation in highly competitive markets.

Dass et al. (2015) empirically analyse the role of the relative protection provided by patent and trade secrets law in the US. They find that the strengthening of trade secret law by U.S. states led to fewer patent applications, increased opaqueness, greater stock illiquidity, and worse announcement reaction to seasoned equity offerings (SEOs). In contrast, the implementation of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) was followed by an increase in patenting, enhanced transparency, greater stock liquidity, and a less negative stock-market reaction to SEOs. Png (2012) studied the impact of changes in U.S. trade secrets law on firms' R&D investment and found a negative effect in low technology industries; and a positive effect in high technology industries. In a study relying on historical data of innovations presented at four global fairs in the second half of the nineteenth and in the early twentieth century, Moser (2012) showed a substantial variation in the use of patenting across sectors which could be linked to differences in effectiveness of patenting and secrecy in these sectors at that time.

The role of patent law as an incentive to use patenting becomes more complex in the case of innovations that are subject to patent thickets and if licensing is a strategic option. Theoretical models suggest that patenting is relatively more attractive than secrecy in such situations. Panagopoulos and Park (2015) look at this strategic capacity of patents and show that patents are preferred over secrecy as they can foster technology transfer by both creating and resolving an IP conflict. Kwon (2012a) considers the situation of patent thickets, i.e. when firms compete for multiple complementary patents (i.e. operating in a patent thicket). In such a case, patent protection will result in a decrease in the R&D investment of firms. In contrast, if firms compete over a single innovation, patent protection will result in an increase in R&D investment. In the case of licensing, and when the propensity of patenting is small, strengthening patent protection can decrease the incentive for firms to innovate (Kwon, 2012b). Licensing is also considered by Bhattacharya and Guriev (2006), who analyse the choice between an open sale after knowledge has been patented, and a closed sale which precludes further disclosure. Contracting parties will choose the closed sale whenever the interim knowledge is more valuable and leakage is sufficiently high.

H2. Degree of innovation competition

The assumption of a sole innovator in the model of Kultti et al. (2007) is rarely found in practice. Most technological markets are characterised by a larger number of firms with similar innovative capacities, which often enter into R&D races for the fastest technological solutions (Lemley, 2012). The degree of innovation competition is commonly seen as a driver for patenting. Where there is the possibility of simultaneous invention, the first inventor will opt for patenting, thereby disadvantaging the others. In contrast, if an innovator has a large technological lead over its competitors, and expects to maintain this lead by soon generating new inventions, the lead innovator will prefer secrecy to patenting (Schneider, 2008; Zaby, 2010). Kultti et al. (2006) present a theoretical model in which patenting is preferred over secrecy, particularly when firms can expect that other firms will develop similar inventions. Other models stress the choice of neither patenting nor secrecy in patent races, but rather voluntary disclosure as a strategy. Gill's (2008) model demonstrates that an innovator with a lead over its competitor opts for strategic disclosure in order to persuade the competitor to exit the patent race. Ponce (2007) shows that the innovator may opt for secrecy, but will disclose some knowledge to prevent a potential second innovator from developing the same innovation and patenting it. Zhang (2012) investigates the impact of innovation arrival rates and the number of firms competing for innovations. Firms that innovate early are more inclined to choose secrecy. A higher innovation arrival rate will increase the incentives to patent, while an increase in the number of firms may cause patenting to occur earlier if the strength of patent protection is high.

H3. Level of innovation

In their seminal paper, Anton and Yao (2004) model the role of the degree of innovation in terms of small vs. major innovations. They demonstrate that in a model with an innovator and a competitor with less innovative capacity, major innovations are not patented but kept secret to prevent imitation by competitors. Pajak (2010) uses data from the French innovation survey and finds, albeit for a very small sample of firms, that smaller innovations are patented while secrecy is used to protect large innovations. In a similar paper, which assumes competitors have the same innovative capacity as the innovator, Mosel (2011) demonstrates that it is rather major innovations that are patented, while patenting small innovations does not pay-off due to high filing costs. These results would imply that the impact of the level of innovation on patenting and secrecy will depend on the competitors' innovative capacity. There are few empirical studies on this issue. Arora et al. (2008) show that most innovations are not worth patenting, but for those it is, patent protection stimulates R&D. Hall et al. (2013) find that firms involved in R&D are more likely to rely on patenting than innovators that do not perform R&D (and will hence have a lower level of technological novelty contained in their innovations). The historical study by Moser (2012) found that patented innovations were more often awarded a prize, indicating that more valuable innovations were more frequently patented.

H4. Type of innovation

Patenting is also preferred over secrecy if the threat of imitation, e.g. by reverse-engineering, is high. In this case, applying for a patent and hence disclosing details about the invention in the patent document would reveal no more information than one could obtain from looking at the innovation. In contrast, if rivals could substantially learn from the information provided in the patent document but could not reverse-engineer the innovation, firms would opt for secrecy (Hall and Harhoff, 2012). In general, reverse-engineering is easier to apply to product innovations. For process innovations that have been developed in-house, and that are not traded, reverse-engineering is largely impossible. For that reason, process innovation will be more likely subject to secrecy while product innovations will be more often protected by patenting. In a theoretical model, Biswas and McHardy (2012) analyse the circumstances under which process innovators will opt for patenting instead of secrecy, even if secrecy is costless. They find that low-cost firms are more likely to opt for patenting. High-cost firms will use patenting only if they can profitably bluff and pass themselves off as a low-costs firm in the market. The incentive to patent rather than maintain secrecy, increases as the probability that the rival firm is a low-cost firm falls, and as the proportion of cost reduction obtained by the rival firm through innovation declines after the underline patent has expired.

H5. Open innovation practices

The way in which firms organise the innovation process is likely to have impacts on their protection strategy. In the literature, there are two views as to how external knowledge sourcing and the choice of protection methods is linked (Arora et al., 2015). The “spillover prevention” approach stresses that collaborating firms favour patenting in order to control spillovers to external partners (Cassiman and Veugelers, 2002), while adopting a secrecy strategy is more difficult when firms are engaged in collaboration (Giarratana and Mariani, 2014). Buss and Pukert (2015) found that firms which outsource R&D are more likely to suffer from IP infringement. Patenting may also be used by firms following an open innovation strategy in order to signal the firm’s innovative capabilities to potential cooperation partners (Alexy et al., 2009; Hagedoorn and Ridder, 2012). The “organisation openness” approach argues that collaborating firms will rather refrain from patenting in order to reduce collaboration with external actors (Laursen and Salter, 2014) as keeping knowledge in-house may impede collaborative knowledge-creating processes. There is some evidence that firms deliberately disclose certain knowledge to the general public (“selective revealing”) in order to spur complementary innovations (Alexy et al., 2013; Henkel et al., 2014). In addition, the strategic use of secrecy has been supported by the emergence of thorough secrecy management in firms (Bos et al., 2015).

There are empirical results to support both views. Cassiman and Veugelers (2002), Cosh et al. (2011), Zobel et al. (2013) and Huang et al. (2014) find a positive relation between openness and patenting. Arora et al. (2015) show that patenting due to openness is higher amongst technologically leading firms, while firms focussing on incremental innovations are less willing to patent. Arundel (2001) finds only weak evidence that participation in cooperative R&D increases the returns of a patent-based protection strategy for product innovations as compared to a secrecy strategy. Laursen and Salter (2014) investigate the “paradox of openness”. While the creation of innovations often requires openness, their commercialization necessitates their protection. Their empirical analysis shows a concave relation between openness and appropriability. Openness first increases with the strength of the appropriability strategy, before displaying the opposite trend. Jensen and Webster (2007) find that firms conducting internal R&D and relying upon secrecy and patenting to protect their innovations are less likely to engage in external knowledge exchange. Another study by Arora et al.

(2015) shows that firms relying on customers and suppliers for their inventions are less likely to patent the focal invention whereas knowledge sourcing from universities and R&D suppliers increases patenting.

H6. Financial constrains

Applying for patents and monitoring potential infringements is costly. Firms with financial constraints may hence opt for protection methods which imply lower costs, such as secrecy. Graham et al. (2009), as well as Cordes et al. (1999), have found that the most significant reason why start-ups and small high-tech firms refrain from patenting are the costs involved. The study by Hall et al. (2013) carried out using data from the UK innovation survey, found that firms reporting financial constraints on their innovative activity tend to prefer secrecy over patenting. In addition, patenting is often subject to economies of scale;larger businesses therefore tend to make greater use of patents (Lerner, 1995; Arundel and Kabla, 1998).

Combining patenting and secrecy

While much of the literature considers patenting and secrecy as substitutes for one another, or even as mutually exclusive protection strategies, they can also complement one another (Hall et al., 2014; Arora, 1997). Graham (2004) argues that firms may keep the codified part of an invention secret, while maintaining the option to later patent the invention. Hegde et al. (2009) stress the role of continuations in patenting which allow individual claims to be altered, thereby extending secrecy with regard to specific claims. In their empirical study, Graham and Hedge (2014) find that a small fraction of U.S. patent applications (7.5%) use a provision to keep their inventions secret before a patent is granted. Small inventors are more likely to prefer disclosure through the patent document over secrecy for their most important inventions.

In a theoretical model, Belleflamme and Bloch (2014) analyse the conditions under which innovators may choose to combine patenting and secrecy as protection strategy in case of complex innovations and an imitation risk. Such a situation will occur if the imitator is required to learn about a large proportion of the innovation in order to be able to usefully exploit it. Otherwise, the innovator will choose to either patent the entire innovation, or keep it secret in its entirety. Mixing patents and trade secrets was also analysed by Ottoz and Cugno (2008, 2011) and Cugno and Ottoz (2006). They demonstrate that in a situation that allows a single innovation to be protected both by patents and trade secrets, strengthening patent breadth may induce a lower level of patenting as innovators will rely on secrecy. Where the part of the technology kept secret is highly relevant for the economic performance of an innovation, and the costs involved in duplicating the innovation are sufficiently high, protection via a strong trade secret is preferable as it saves duplication costs. In addition, secrecy is superior over patents due to the lack of an independent invention defence in patent law.

The hybrid use of patents and trade secrets has also been studied from a legal perspective. Perng Pan and Mion (2010) illustrate that an appropriate combination of these two protection methods is particularly important where aspects of green technology can be partitioned into different segments, some of which are easy to re-design or replicate, and some which are not. Erkal (2004) stresses that trade secret law complements patent law in earlier stages of the innovation process by allowing innovators to work on their ideas until they become patentable. Afterwards, the two protection methods become substitutes for one another.

Patenting, secrecy and firm performance

Effective protection of innovations should give innovators a performance premium as they are then able to prevent others from imitating their innovation. It should hold for all types of protection methods, that effectively protected innovations enjoyed higher levels of innovation success. There are rather few empirical studies investigating this relationship. Hussinger (2006) used German innovation data and found that sales from product innovations are higher for firms rating patents as important for protecting their innovations. She does not observe a significant impact from secrecy on new product sales. Hall et al. (2013) use UK innovation data and identify a strong impact of patents (as well as trade marks) on sales from new-to-the-market innovations, but no impact on innovations that were only new to the firm. Informal protection methods, including secrecy, have a positive impact on both categories of product innovations, though the effect on new-to-firm innovations is lower and less significant. These findings suggest that patent protection is better suited to effectively preventing competitors from imitating an innovation. It would also seem that firms overrate the effectiveness of secrecy as a protection method, perhaps because they lack a reference value for innovation success when using patent protection.

The impacts of patenting on firm performance have received significant attention in empirical research since the seminal paper by Griliches (1981). Griliches found a positive impact of a firm’s patent stock on the market value of publicly listed firms. Other studies support this result. Hanel (2008) uses data from the Canadian innovation survey and finds a positive impact of IP protection on profitability. Czarnitzki and Kraft (2010) analyse German innovation data and find that a firm’s patent stock has a strong and robust positive effect on profitability. Rogers et al. (2007) investigate a large set of UK small and medium-sized enterprises (SMEs) and find a positive effect of domestic (UK) patents on profitability. For international (EPO) patents, the effect is negative for SMEs which have existed for less than 10 years.

To the best of our knowledge, no empirical studies have yet been conducted into the impact of trade secrets on firm profitability. There are also no empirical analyses concerning patenting and secrecy on process innovations success. In addition, no empirical work has yet considered the interaction between patenting and secrecy when it comes to performance impacts of protection strategies. This paper aims to fill this gap to some extent.

3. Model, Data and Descriptive Results

Models

In this paper, we estimate three types of empirical models, following Hall et al. (2013): (i) the determinants of using patenting and secrecy as methods to protect a firm's innovations, (ii) the impact of patenting and secrecy effectiveness on a firm's product and process innovation output, and (iii) the impact of patenting and secrecy effectiveness on firm profitability. We extend the analysis previously conducted by Hall et al. (2013), by considering a larger number of potential determinants, by looking at process innovation success, and by using firm profitability as a performance measure (rather than employment growth). Most importantly, we are able to run our analysis for a sub-sample of innovators with only a single innovation. This allows us to establish the determinants and the impacts of combining patent and secrecy strategies.

The first model relates a firm's *i* decision to use patents or trade secrets as a protection methods (*pm*) to a set of variables that are intended to represent the six hypotheses discussed above (strength of IP law - *ip_str*, degree of innovation competition - *in_com*, level of innovation - *in_lev*, type of innovation - *in_typ*, open innovation practices - *in_op* and financial constraints - *fi_con*):

$$pm_i = \alpha + \beta_1\, ip\_str_i + \beta_2\, in\_com_i + \beta_3\, in\_lev_i + \beta_4\, in\_typ_i + \beta_5\, in\_op_i + \beta_6\, fi\_con_i + \chi X_i + \varepsilon_i \quad [1]$$

where *pm* represents the use and effectiveness of patents and trade secrets. *pm* is operationalised in different ways. The main model variant employs the four combinations of using patents and trade secrets (none of them, both of them, only patenting, only secrecy). Other model variants employ binary measures (use of patents, use of trade secrets, high importance of patents, high importance of secrets, importance of patents dominate over trade secrets, importance of trade secrets dominate over patents) or the firms' assessment of the effectiveness of the two protection methods (measured at a 4-point Likert scale). In another model variant, the structure of Arundel (2001) and Hall et al. (2013) is followed by using a measure of the relative importance of trade secrets over patents. This measure gives the difference between the effectiveness rating of trade secrets and the effectiveness rating of patents and can hence range from +3 (trade secrets are highly effective, but patents are not effective at all) to -3. The vector *X* includes the size and age of a firm as well as the industry in which a firm operates.

The second model relates the level of innovation output (*in_out*) a firm *i* obtained in period *z* to the chosen protection method in period *t*:

$$in\_out_{iz} = \alpha + \beta\, pm_{it} + \chi\, X_{it} + \varepsilon_{iz} \qquad [2]$$

where *in_out* covers measures of product innovation (sales with new products) and process innovation success (cost reduction). Control variables (vector *X*) include size, age and the level of innovation input.

The third model relates a firm's financial performance (profit margin) in period *z* to the chosen protection method in period *t* while controlling for the effect of innovation output and other firm characteristics as well as a firm's stock of trade marks (*tm*) since :

$$perf_z = \alpha + \beta_1\, pm_{it} + \beta_2\, tm_{it} + \chi_1\, in\_out_{it} + \chi_2\, X_{it} + \varepsilon_{iz} \qquad [3]$$

In line with Hall et al. (2013), all models are restricted to innovating firms. These are firms which have introduced a product or a process innovation in the last three years. This restriction ensures that only firms that have had to decide whether and how to protect recently introduced innovations are included in the analysis.

Data

Our empirical analysis is based on data from the German innovation survey. This survey is part of the Community Innovation Surveys (CIS) of the European Commission. In contrast to most national contributions to the CIS, the German survey is based on a panel sample and conducted annually. The survey is conducted by the Centre for European Economic Research located in Mannheim, and is hence also called the "Mannheim Innovation Panel" (MIP) (see Peters and Rammer, 2013, for more information on the panel nature of the survey). The MIP data have been matched with patent application data (from the European Patent Office and the German Patent and Trade Mark Office) and with trade mark application data (at the Office for Harmonization in the Internal Market and at the German Patent and Trade Mark Office). This allows us to complement the survey data with firm-specific patent indicators and to control for the use of trade marks as an alternative protection method.

For this paper, we use two recent survey waves that contained information on the use and importance of different methods to protect a firm's innovations (see the Appendix for the exact wording and layout of the questions). Both the 2010 and 2012 surveys asked firms to rate the importance of eight methods used to protect a firm's IP and innovations (see the Annex for the exact wording of the questions). The eight methods include patents, utility patents, industrial designs, trade marks, copyrights, lead time advantages, complexity of goods or services, and secrecy. For each method firms were required to state whether they had used this method within the previous three-year period (2008 to 2010, and 2010 to 2012, respectively), and how important a role it played in their protecting efforts. In 2010, importance was rated in terms of the role methods played in protecting the firm's IP, while in 2012, the question was phrased differently, asking firms to rate the effectiveness of each method in terms of maintaining or increasing the competitiveness of product and process innovations. In both surveys, importance was measured on a three-point Likert scale (high, medium, low). We use this information to build five types of dependent variables for model [1]: (i) categorical variables measuring the importance of patenting and secrecy, respectively, as a method for protecting a firm's innovations on a 4-point Likert scale (no, low, medium, high importance); (ii) dummy variables indicating the use of patenting and secrecy, respectively; (iii) dummy variables for patenting and secrecy, respectively, having a high importance for protecting innovations; (iv) dummy variables for using neither patenting nor secrecy, for using both, and for using only one of the two methods; (v) dummy variables for firms that either rate both patenting and secrecy of medium or high importance or only one of the two; (vi) an indicator measuring the difference in importance between patenting and secrecy, following Arundel (2001) and Hall et al. (2013).

A main drawback of existing firm-level analysis of patenting and secrecy is that many firms advance several innovations at the same time. If one only knows whether a firm has used patenting or secrecy for any innovation in a certain period of time, as is the case with CIS-type data, it is impossible to determine which innovation was protected by which method. One solution is to collect information on protection methods for only a single innovation, e.g. the firm's most important innovation (see Arora et al., 2016). A drawback of this approach is that there might be spillovers from other innovations in the same firm on the choice of protection methods and their effectiveness for the single innovation one is looking at. Another option is to focus on firms with only one innovation. This is they was we follow in this paper. Fortunately, the MIP data collects information on the number of different innovation projects a firm has conducted with the three-year reference period, distinguishing between successfully completed, ongoing and discontinued projects.[1] This allows us to identify single innovation firms, i.e. firms that have completed only one innovation project during the three-year period considered, and which have neither ongoing, nor discontinued projects. It would seem that 24% of all innovating firms in our sample are single innovation firms. 39% of these single innovation firms combine patenting and secrecy.

By focussing our analysis on single innovators we can be sure that the protection methods used refer to one and the same innovation. This choice of course limits the conclusions we can draw from this study as our findings apply only to this specific group of innovators. This limitation does not seem to be particularly severe, however, as single innovators do not differ

[1] This question as well as a series of other questions we use in this paper go beyond the harmonised CIS questionnaire and are not included in the questionnaires of other countries that participate in the CIS data collection effort.

substantially from the average innovator. Descriptive statistics (see Table 7 in the Appendix) show that on average, single innovators are younger, there is not, however, a significant difference in size since, with many large firms also included in this group. The market environment in which single innovators operate seems to be rather similar to that of multiple innovators. There are also no significant differences with respect to capital intensity, innovation intensity and financial performance (profit margin). A main difference is that single innovators report a lower level of innovation performance both in terms of continuous in-house R&D activity and innovation success (introduction of new-to-market innovations, sales share of new-to-firm innovations, cost reduction from process innovation). In addition, they are less frequently process innovators and are less often engaged in cooperation with other businesses.

In order to compare the results obtained for single innovators with the entire group of innovating firms, we also run our models for the entire sample of innovators and report the results for both samples.

Variables

In order to test the six hypotheses discussed in section 2, we use the following variables in the protection method decision model [1]:

- *Strength of IP law (H1)*: In general, patent and trade secrets law is uniform for all firms in Germany. The effectiveness of patent law protection may vary by field of technology and sector, however, depending on the legal possibility of patenting new knowledge, and on court practice in dealing with patent litigation. Following Hussinger (2006), we calculate the proportion of innovating firms using patents as an indicator for the strength of patent law.[2] This proportion is calculated by dividing the number of firms with valid patents (granted patents that are still active) by the number of innovating firms, using the 3-digit sector level. The number of firms in Germany with valid patents is taken from the Patstat database which has been linked with company data (provided by Creditreform, the German source of the Bureau van Dijk databases) to establish the sector code of patent applicants. The number of innovating firms is calculated on the basis of the innovation survey data using weighted results. In addition, we calculate the share of valid patents in a sector that has been licensed out to third parties, using information on the number of out-licensed patents collected in the 2010 wave of the MIP. As there is no evidence to suggest that trade secret law, part of common law in Germany, varies systematically by sectors or technology, we do not use an indicator for the strength of trade secret law.

[2] We do not follow Hussinger (2006) exactly as she calculated the share of firms using patents and secrecy from the sample she used for model estimations. We believe that this procedure suffers from technical endogeneity since the dependent variable is used to construct an independent model variable.

- *Degree of innovation competition (H2)*: We use a variable that captures the degree of technological uncertainty, assuming that a market with high technological uncertainty is characterised by a large number of firms competing for innovation. If a firm is the dominating innovator in its market, technological uncertainty shall be low for this firm. The degree of technological uncertainty has been measured directly in both waves of the MIP. In order to control for the general intensity of competition, we use the number of competitors in the firm's main product market and separate firms with a high number of competitors (16 or more) from those with few competitors (5 or less). In addition, we add a dummy variable indicating whether the number of competitors has recently increased.

- *Level of innovation (H3)*: Following Hall et al. (2013), we distinguish new-to-the-market innovations from innovations only new to the firm. In addition, we use information on the extent of a firm's innovation activities (innovation expenditure per employee) to control for the amount of new knowledge generating by the firm's innovative activities.

- *Type of innovation (H4)*: As suggested by the theoretical literature, we distinguish product and process innovation. Since service innovations are virtually excluded from patent protection under German and European patent law, we also differentiate between product innovation for manufactured goods and product innovation for services.

- *Open innovation practice (H5)*: We use a dummy variable that indicates whether a firm engages in innovation cooperation with external partners, distinguishing between cooperation with business partners on the one hand (clients, suppliers, competitors), and partners from universities and private or public research organisations on the other.

- *Financial constraints (H6)*: We measure both internal and external financial constraints. For likely internal financial constraints we use a firm's lagged profitability. External financial constraints are measured by the credit rating a firm was given by Germany's largest credit rating agency (Creditreform).

For the *innovation performance model* [2] we use three dependent variables: sales from new-to-the-market innovations, sales from innovations that were only new to the firm ('imitations'), and the degree of cost reduction resulting from process innovations. While the first two variables are well established in innovation research (see Mairesse and Mohnen, 2010) and were also used by Hussinger (2006) and Hall et al. (2013), our indicator of process innovation performance has as yet rarely been used (Piening and Salge, 2015, being one of the few examples), despite the fact that the MIP has included this variable since 1994. The independent variables of the innovation performance model include, in addition to patenting and secrecy, innovation input, size and age. Innovation input is measured by innovation intensity (innovation expenditure per employee) and continuous R&D activity as a measure of the degree of novelty of the generated knowledge (see Laursen and Salter, 2006; Leiponen and Helfat, 2010; Klingebiel and Rammer, 2014). Since performance impacts of protection strategies may be lagged, we test the model with different lags between the reference period of the protection strategy and the year for which innovation success is measured.

The *firm performance model* [3] investigates the impact of the chosen protection strategy on firm profitability. We employ a profitability model that has been previously used by other authors using the MIP data (Rexhäuser and Rammer, 2014; Czarnitzki and Kraft, 2010). The dependent variable is the profit margin, i.e. pre-tax profits as a share of sales. Firms reported return on sales within nine ordered categories with known thresholds. Control variables include fixed capital intensity (assets per employee), the type of innovation introduced (new-to-the-market product innovation, new-to-the-firm product innovation, cost-reducing process innovation) as well as an index on the degree of competition, following Rexhäuser and Rammer (2014). Given that branding may add an additional layer of product differentiation and may increase the customer's willingness to pay through positive reputation effects (see Crass, 2014), we also include a dummy for branding activities (i.e. positive number of valid trade marks). As is the case with innovation performance, we also consider a potential lag between the time at which a protection strategy was chosen, and the year for which profitability is measured.

All models include size, firm age and sector as well as a dummy variable for the year of observation as further controls. Descriptive statistics of the dependent and independent model variables are depicted in Table 8 to Table 10 in the Appendix.

Descriptive Results

The share of innovating firms using patents to protect their IP and their innovations is significantly smaller than the share of firms using trade secrets. In the 2012 survey, 74.1% of all innovating firms, that is to say all firms having introduced product or process innovations, used trade secrets, while only 47.8% used patents.[3] For single innovators, these percentages are smaller with respect to the use of trade secrets (62.5%), and at a similar level for patents (45.0%).

Table 1: Use of patents and trade secrets in innovating firms in Germany 2010 and 2012

	Patents		Trade Secrets	
	2010[a)]	2012[b)]	2010[a)]	2012[b)]
a) innovating firms with a single innovation				
Use	38.4	45.0	60.6	62.5
Therein: high importance / effectiveness	*12.6*	*15.5*	*39.5*	*17.7*
Therein: medium importance / effectiveness	*10.5*	*16.4*	*15.3*	*23.4*
Therein: low importance / effectiveness	*15.4*	*13.2*	*5.7*	*21.3*

[3] All descriptive results are based on weighted data. The German Innovation Survey is a sample survey based on a stratified random sample with 896 strata (56 NACE 2-digit sectors, 8 size classes, 2 regions). Weights are calculated using population figures from the official German Business Register. Weights have been adjusted for a potential non-response bias between innovating and non-innovating firms. See Aschhoff et al. (2013) for details on the weighting method.

Not used	61.6	55.0	39.4	37.5
b) all innovating firms				
Use	36.8	47.8	57.3	74.1
Therein: high importance / effectiveness	*11.9*	*18.8*	*34.5*	*24.8*
Therein: medium importance / effectiveness	*9.3*	*16.6*	*14.7*	*25.7*
Therein: low importance / effectiveness	*15.6*	*12.5*	*8.2*	*23.6*
Not used	63.2	52.2	42.7	25.9

a) Used for protecting the intellectual property of a firm. - b) Used for maintaining or increasing the competitiveness of product and process innovations.
Source: German Innovation Survey (CIS 2010, CIS 2012), CIS core sectors only, weighted results.

The difference is less marked when looking at firms which report both patenting and secrecy to be being highly effective: 24.8% of all innovating firms (17.7% of single innovators) perceive secrecy as being highly effective for maintaining or increasing the competitiveness of their innovations, whereas 18.8% (single innovators: 15.5%) report this to be the case for patents.

The results for the 2010 survey differ from those from 2012 insofar as the proportion of innovating firms using secrecy or patenting is lower (57.3% for trade secrets, 36.8% for patents), whilst a larger share of firms rate secrecy as highly effective (34.5%). Interestingly, the differences between the two surveys are lower for single innovators. The main reason for the different results in regards to secrecy is to be found in the different wording of the question. While the 2012 survey directly relates to the effectiveness of the innovations' competitiveness, the 2010 survey refers to a firm's intellectual property in general. The results suggest that trade secrets are more effective in protecting a firm's general IP (which may also include IP not related to product or process innovation) than in protecting the competitiveness of innovations in the market.

Table 2: Use of patents and trade secrets in innovating firms in Germany 2012, by size class (no. of employees)

	Patents			Trade Secrets		
	10-49	50-249	250+	10-49	50-249	250+
a) innovating firms with a single innovation						
Used	42.3	50.9	81.6	61.3	64.5	86.5
Therein: high effectiveness	*13.6*	*19.1*	*44.3*	*18.5*	*15.8*	*9.9*
Therein: medium effectiveness	*15.1*	*18.7*	*36.0*	*22.7*	*21.7*	*68.0*
Therein: low effectiveness	*13.5*	*13.1*	*1.3*	*20.0*	*26.9*	*8.5*
Not used	57.7	49.1	18.4	38.7	35.5	13.5
b) all innovating firms						
Used	40.9	58.6	72.8	71.2	79.1	82.4
Therein: high effectiveness	*14.6*	*22.8*	*41.2*	*24.9*	*23.4*	*28.2*
Therein: medium effectiveness	*13.1*	*23.8*	*23.1*	*23.2*	*29.6*	*34.3*
Therein: low effectiveness	*13.1*	*12.0*	*8.4*	*23.1*	*26.1*	*20.0*
Not used	59.1	41.4	27.2	28.8	20.9	17.6

Source: German Innovation Survey (CIS 2012), CIS core sectors only, weighted results.

Our results confirm the findings of earlier empirical studies on the use of patents and secrecy which have frequently found that a higher proportion of innovating firms rely on secrecy than patenting (see Levin et al., 1987; Brouwer and Kleinknecht, 1999; Cohen et al., 2000, 2002; Arundel, 2001; Hanel, 2008). When differentiating by size class, the findings become more diverse. Large firms still use trade secrets more frequently than patents, but they rate the effectiveness of patenting as higher than for secrecy. This is particularly true for single innovators. Among medium-sized firms, a similar share of all innovators rate patents and trade secrets as being highly effective. Among firms with a single innovation, more find patenting highly effective than secrecy. Small firms more often report secrecy as being highly effective than they do patenting. This holds for all innovators and for single innovators.

Table 3: Combination of patents and trade secrets in innovating firms in Germany 2012

		Trade Secrets			
		Used, high effectiveness	Used, medium effectiveness	Used, low effectiveness	Not used
a) innovating firms with a single innovation					
Patents	Used, high effectiveness	5.5	4.8	2.7	2.5
	Used, medium effectiveness	2.8	5.8	5.6	2.2
	Used, low effectiveness	2.6	2.2	6.8	1.7
	Not used	6.9	10.6	6.3	31.2
b) all innovating firms					
Patents	Used, high effectiveness	7.9	5.6	3.6	1.7
	Used, medium effectiveness	3.7	6.7	4.2	2.0
	Used, low effectiveness	3.1	3.1	4.9	1.3
	Not used	10.1	10.3	10.9	20.9

Source: German Innovation Survey (CIS 2012), CIS core sectors only, weighted results.

Firms regularly combine patenting and secrecy to protect their innovations. In 2012, only 20.9% of all innovating firms in Germany used neither patenting nor secrecy, while 42.8% used both. Firms that neither use patenting nor secrecy either use other protection methods (e.g. trade marks, copyrights, industrial designs, lead time advantage) or refrain from any protection, particularly if their innovations are imitations of other firms' original innovations. Most firms that seek patent protection also use trade secrets; only 10% of patent users did not rely on secrecy in 2012. Among all firms employing secrecy as a protection method, 58% also used patents, while 42% did not. The results do not substantially change when looking at innovating firms with a single innovation. 38.8% of these single innovators used both patents and trade secrets. 5.5% stated that both were highly effective, with 18.9% giving both methods the rating of at least medium effectiveness.

4. Estimation Results

Protection Method Decision

We analyse a firm's choice to use secrecy or patenting to protect its innovation and IP, and the perceived effectiveness of the two instruments through different measures, as described above. Table 4 reports the results for the four combinations of using secrecy and patenting. In particular, this model variant allows the relevance of the six hypotheses on a firm's choice to use both protection methods simultaneously, or to rely only on one of the two, to be investigated. For comparison, Table 11 (in the Appendix) shows the model results when looking separately at a firm's decision to use trade secrets or patents (by allowing error terms to be correlated), and Table 12 presents the respective estimation results for firms evaluating the effectiveness of trade secrets and patents as high. The results of ordered probit regressions on the firm's Likert scale evaluation of the effectiveness of secrecy and patenting are shown in Table 13. Further model variants look at the relative importance of secrecy over patenting by taking the difference between the secrecy and patenting ratings, as done in Hall et al. (2013) (see Table 14), and by separating firms that rate the effectiveness of both secrecy and patenting as being high of medium from those that rate only one of the two methods as such (Table 15).

All models are estimated for single innovators and all innovators. Comparing the results gives some indication of the robustness of findings for firms with multiple innovations (which is the standard case in most of the existing empirical literature) when it comes to the determinants and effects of using both secrecy and patenting as protection methods.

The estimation results of the various model variants reveal a number of common findings. H1 on the strength of IP law is confirmed as firms operating in sectors with a high share of innovators with patents are more likely to prefer patenting and are less likely to rely on secrecy. The results hold for both single innovators and for all innovators. We do not find a robust result for the impact of the degree of licensing on the choice of the protection method. In some model variants, we find a positive impact of the degree of licensing of patents on the effectiveness of secrecy, which holds only for all innovators, but not for single innovators.

A high degree of competition, measured in terms of the number of competitors in a firm's main market, acts rather as an incentive to use neither secrecy nor patenting, as suggested by the model provided by Gill (2008). This finding holds for single innovators who rate the effectiveness of both protection methods as being significantly lower if they operate in markets with many competitors (see Table 12 and Table 13). High technological uncertainty is a driver for combining secrecy and patenting both in firms with a single innovation, and in the entire group of innovators. This is in line with the findings illustrated in Ponce's (2007) model on preventing competitors from developing the same innovation.

Single innovators with new-to-market innovations favour patenting over secrecy. We find a positive and significant coefficient both for using both patenting and secrecy, and for using only patenting. Single innovators that heavily invest in innovation prefer to combine both protection methods and are much less likely to refrain from using either of the two. This result supports H3 and is in line with the literature which stresses that patenting is more commonly used for large innovations (Moser, 2011). While we find a negative impact of both new-to-market innovations and innovation intensity on using only secrecy for all innovators, this effect becomes insignificant when looking at single innovators, suggesting that the negative effect is the result from different protection strategies for different innovations. The alternative variable specifications of combining secrecy and patenting support these results (see Table 14 and Table 15).

Table 4: Determinants of using secrecy and/or patenting to protect a firm's innovations / IP: results of probit models (estimated coefficients, significance levels in brackets)

		Firms with a single innovation				All innovators			
		Neither secrecy nor patenting	Only patenting	Only secrecy	Both patenting and secrecy	Neither secrecy nor patenting	Only patenting	Only secrecy	Both patenting and secrecy
Strength of IP Law	Share of innovators with patents	-0.554* (0.065)	0.506 (0.231)	-0.716*** (0.008)	1.005*** (0.000)	-1.134*** (0.000)	0.505** (0.010)	-0.643*** (0.000)	1.240*** (0.000)
	Share of out-licensed patents	-0.009 (0.747)	-0.047 (0.341)	0.012 (0.644)	0.008 (0.772)	-0.005 (0.756)	-0.046 (0.148)	0.009 (0.564)	0.017 (0.244)
Degree of innovation competition	High technological uncertainty (D)a)	-0.370*** (0.000)	-0.238 (0.102)	0.061 (0.482)	0.279*** (0.001)	-0.133*** (0.003)	-0.086 (0.179)	-0.006 (0.879)	0.122*** (0.002)
	Large no. of competitors (D)[a)]	0.219** (0.049)	-0.142 (0.481)	-0.013 (0.904)	-0.156 (0.151)	0.009 (0.867)	-0.216** (0.017)	0.026 (0.604)	0.017 (0.740)
	Small number of competitors (D)[a)]	0.115 (0.255)	0.094 (0.516)	-0.118 (0.211)	-0.050 (0.591)	-0.004 (0.935)	-0.080 (0.222)	-0.087** (0.049)	0.076* (0.077)
	Competition has increased (D)[a)]	0.006 (0.951)	0.192 (0.234)	0.058 (0.544)	-0.096 (0.323)	-0.081* (0.095)	-0.015 (0.840)	0.014 (0.743)	0.035 (0.426)
Level of innovation	Market novelty (D)[a)]	-0.542*** (0.000)	0.411*** (0.004)	-0.100 (0.293)	0.378*** (0.000)	-0.527*** (0.000)	0.234*** (0.000)	-0.082* (0.059)	0.369*** (0.000)
	Innovation intensity (log)[a)]	-0.152*** (0.000)	0.017 (0.710)	0.001 (0.968)	0.105*** (0.001)	-0.095*** (0.000)	-0.060** (0.010)	-0.030** (0.045)	0.102*** (0.000)
	No innovation expenditure (D)	1.222*** (0.000)	-0.664 (0.127)	-0.160 (0.491)	-0.794*** (0.001)	1.004*** (0.000)	0.142 (0.428)	-0.097 (0.370)	-0.862*** (0.000)
Type of innovation	Process innovator (D)	0.101 (0.238)	-0.098 (0.458)	0.039 (0.625)	-0.113 (0.160)	0.018 (0.672)	-0.143** (0.021)	0.025 (0.522)	-0.005 (0.904)
Open innovation practice	Cooperation with businesses (D)[a)]	0.014 (0.915)	0.028 (0.873)	-0.086 (0.441)	0.114 (0.283)	-0.122* (0.064)	-0.002 (0.979)	0.073 (0.176)	0.012 (0.809)
	Cooperation with research (D)[a)]	-0.265** (0.025)	-0.092 (0.561)	-0.159 (0.128)	0.334*** (0.001)	-0.336*** (0.000)	-0.066 (0.408)	-0.224*** (0.000)	0.388*** (0.000)

Table 4: Ctd.

		Firms with a single innovation				All innovators			
		Neither secrecy nor patenting	Only patenting	Only secrecy	Both patenting and secrecy	Neither secrecy nor patenting	Only patenting	Only secrecy	Both patenting and secrecy
Financial constraints	Credit rating (lagged)	0.051	0.002	-0.023	-0.031	0.040	-0.032	-0.007	-0.022
		(0.324)	(0.985)	(0.656)	(0.567)	(0.158)	(0.438)	(0.803)	(0.402)
	High profit margin (lagged)[a)]	-0.006	-0.133	-0.036	0.058	-0.039	-0.100	-0.013	0.041
		(0.951)	(0.432)	(0.710)	(0.557)	(0.459)	(0.201)	(0.791)	(0.382)
	Low profit margin (lagged)[a)]	-0.016	-0.014	-0.058	0.066	-0.078	0.087	0.025	-0.005
		(0.902)	(0.946)	(0.643)	(0.592)	(0.228)	(0.330)	(0.675)	(0.931)
Controls	Age (log # years)	0.153***	0.008	-0.006	-0.136***	0.076***	0.042	-0.023	-0.062***
		(0.001)	(0.915)	(0.894)	(0.002)	(0.000)	(0.175)	(0.228)	(0.001)
	Size (log # employees)	-0.101***	0.023	-0.086**	0.150***	-0.113***	0.019	-0.095***	0.151***
		(0.004)	(0.649)	(0.012)	(0.000)	(0.000)	(0.351)	(0.000)	(0.000)
Applies to		366	57	339	484	1,543	271	1,408	2,635
No. of observations		1,246	1,246	1,246	1,246	5,857	5,857	5,857	5,857

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Single innovators with a process innovation do not show a clear preference for secrecy or patenting. The estimation results for the relative importance of the two protection strategies suggest that process innovators give secrecy a higher rating than patenting (Table 14). But when looking at which of the two strategies dominate, no significant impact is found (Table 15). Investigating the effect of process innovations on the efficiency rating of the two methods separately, we find a significant negative impact on patenting but no impact on secrecy (see Table 11 to Table 13). This is in some contrast to the findings for all innovators which also show a weakly significant positive effect on secrecy. We cannot therefore support the view commonly expressed in the literature that process innovators opt for secrecy over patenting (H4).

Single innovators that collaborate with other businesses do not favour a certain protection strategy. The situation is very different for firms co-operating with universities and other research institutions. Whilst they are more likely to combine secrecy and patenting, however, they do not rate one method as being more effective than the other. Our results suggest that firms tend to follow organisational openness in collaboration with business partners but try to prevent knowledge outflows when collaborating with other research bodies, by both enforcing confidentiality agreements and patenting critical technological knowledge that has been developed during cooperation. The results for all innovators are largely in line with those for single innovators, though we find that it is the case for all innovators that if they cooperate with research institutions, they are less likely to rely only on secrecy. This result does not hold for single innovators.

Our last hypotheses on the role of financial constraints cannot be confirmed with our data. We do not find a higher propensity to rely on secrecy rather than patenting for firms with lower financial resources. Most indicators of a firm’s internal and external financial situation are insignificant in the majority of model variants. There is some indication that single innovators with a high level of profitability rate secrecy as being more effective than patenting, which is in contrast to the theoretical expectation.

With respect to the control variables for age and size we find that younger firms as well as larger firms are more likely to rely on a combined strategy of secrecy and patenting. While the result for larger firms is to be expected, as a combined strategy is more demanding and tends to require more resources, the higher propensity of young firms may indicate that their innovations are more vulnerable to being copied or imitated by others as they lack complementary assets that can be used to protect their innovations such as reputation or brand value.

Innovation Output

The results of the innovation output models suggest that combining patenting and secrecy as protection methods yields higher returns with new-to-market innovations. For single innovators, the immediate effect of relying only on patenting is higher, but in the following year firms are more likely to achieve more innovative sales if they have used a combined protection strategy (see Table 16). This result is supported by Table 17 which shows a weakly significant negative effect of the relative importance of secrecy over patenting for the immediate new product success, but not significant effect if innovative sales in the following year are evaluated.

We do not find a significant impact of the chosen protection method on innovation success with product imitations, suggesting that this type of innovation is difficult to effectively protect by using these two methods. For cost savings from process innovation, there is a slightly positive impact of single innovators that rely more on secrecy than on patenting.

When comparing the results for single innovators with those for all innovators, it becomes evident that the strong effect of combining secrecy and patenting on the innovation success of product imitations and process innovations, which can be seen for all innovators, is not seen in the case of firms with a single innovation. The positive effects of a combined strategy found for all innovators may rather reflect positive output effects of a diversified innovation strategy which combines new-to-market innovations with product imitations and process innovation. Such positive output effects of diversified innovators may rest on synergies in marketing or shared development costs. The ‘combined protection strategy’ may be an artefact at the firm level if each type of innovation is protected by a specific single method.

Another remarkable difference is the higher innovation output of firms that only use secrecy to protect their innovations (compared to firms that neither use secrecy nor patenting). This positive effect is only present for all innovators, but not for single innovators. This may also suggest that secrecy is used to protect other innovations and is not a determining factor for the innovation success in terms of product imitation sales and cost reduction. One should keep in mind, however, that innovation success of firms with a single innovation may not be fully comparable to innovation success of firms with multiple innovations if the former lack certain capabilities required to successfully commercialise innovations.

Table 5: Effects of using secrecy and patenting on innovation success: results of OLS models (estimated coefficients, significance levels in brackets)

	Firms with a single innovation						All innovators					
	New-to-market innovations		Only new-to-firm innovations		Cost reductions owing to process innovations		New-to-market innovations		Only new-to-firm innovations		Cost reductions owing to process innovations	
	No lag	No lag	1 year lag	No lag	1 year lag	no lag	1 year lag	1 year lag	No lag	1 year lag	No lag	1 year lag
Secrecy only (D)	0.380*	0.478	0.410	0.336	-0.012	0.282	0.605***	0.352*	0.411***	0.830***	0.224*	0.926***
	(0.087)	(0.200)	(0.159)	(0.506)	(0.960)	(0.539)	(0.000)	(0.089)	(0.006)	(0.001)	(0.081)	(0.000)
Patenting only (D)	2.034***	1.196	-0.382	0.033	-0.536	0.169	1.591***	1.367***	0.388	0.530	-0.216	0.475
	(0.000)	(0.171)	(0.495)	(0.972)	(0.176)	(0.814)	(0.000)	(0.001)	(0.160)	(0.243)	(0.376)	(0.355)
Both secrecy and patenting (D)	1.131***	1.311***	0.252	0.116	-0.186	0.452	1.398***	0.910***	0.418***	0.741***	0.248*	0.993***
	(0.000)	(0.001)	(0.400)	(0.819)	(0.414)	(0.243)	(0.000)	(0.000)	(0.005)	(0.003)	(0.052)	(0.000)
Size (log # employees)	0.115	0.143	0.357***	0.817***	0.452***	0.510***	0.470***	0.554***	0.750***	0.975***	0.695***	0.854***
	(0.163)	(0.289)	(0.001)	(0.000)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age (log # years)	0.131	0.222	0.039	0.037	0.002	0.039	0.005	-0.124	0.081	0.250***	-0.098*	-0.015
	(0.173)	(0.211)	(0.759)	(0.865)	(0.981)	(0.843)	(0.923)	(0.203)	(0.165)	(0.007)	(0.065)	(0.890)
Innovation intensity (log)[a)]	0.236***	0.264**	0.220**	0.307**	0.125*	0.307**	0.322***	0.293***	0.265***	0.307***	0.205***	0.376***
	(0.001)	(0.016)	(0.014)	(0.046)	(0.069)	(0.032)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
No innovation expenditure (D)	-1.731***	-1.817**	-1.385**	-3.791***	-0.765	-2.707***	-2.129***	-2.357***	-1.132***	-2.926***	-1.696***	-2.632***
	(0.000)	(0.019)	(0.046)	(0.000)	(0.134)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Continuous R&D (D)[a)]	1.003***	1.599***	-0.358	1.317***	0.530***	0.568	1.163***	1.136***	0.469***	1.419***	0.275**	0.771***
	(0.000)	(0.000)	(0.159)	(0.006)	(0.008)	(0.207)	(0.000)	(0.000)	(0.000)	(0.000)	(0.018)	(0.002)
No. of observations	1,033	363	1,033	360	1,033	257	4,662	1,676	4,662	1,648	4,662	1,229

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Firm Profitability

The protection strategy chosen by an innovating firm has rather little short-term impacts on the firm's profitability. We find a weakly significant positive impact for single innovators that report that only secrecy, and not patenting, is highly effective in protecting their innovations/IP (Table 6). This effect is of a similar magnitude for all innovators (about 1 percentage point higher profit margin), but shows a higher significance level, which may be due to the larger number of observations. If we look at the profitability in the same year that an innovation has been introduced, we also find a positive effect for all innovators reporting that only patenting is effective. Firms that rate both secrecy and patenting as being highly effective do not yield higher profit margins. Indeed, the interaction seen where both secrecy and patenting are rated as highly effective is in fact negative for all innovators. This suggests that combing both protection methods is associated with higher costs but no additional level of protection.

Table 6: Impact of effectiveness of secrecy and patenting on firm profitability: results of interval regression models (estimated coefficients, significance levels in brackets)

	Firms with a single innovation		All innovators	
	No lag	1 year lag	No lag	1 year lag
Highly effective: secrecy only (D)	0.950 (0.111)	1.513* (0.068)	0.935*** (0.001)	0.884** (0.020)
Highly effective: patenting only (D)	-0.919 (0.275)	-1.455 (0.187)	0.686* (0.068)	-0.460 (0.395)
Highly effective: both secrecy and patenting (D)	0.638 (0.415)	-0.049 (0.963)	0.494 (0.152)	0.772 (0.108)
Valid trade marks (D)	1.126 (0.106)	1.935** (0.045)	0.472* (0.093)	0.993** (0.011)
Size (log # employees)	-0.484*** (0.008)	-0.310 (0.204)	-0.154** (0.037)	-0.431*** (0.000)
Age (log # years)	0.152 (0.541)	0.400 (0.239)	0.206* (0.059)	0.429*** (0.008)
Market novelty (D)	0.156 (0.812)	-0.061 (0.943)	-0.066 (0.826)	0.626 (0.144)
Product imitation (D)	-0.032 (0.958)	0.348 (0.667)	-0.142 (0.622)	0.347 (0.395)
Process innovation (D)	0.942* (0.058)	1.469** (0.030)	0.527** (0.020)	1.065*** (0.001)
Capital intensity (€ per employee, log)[a)]	-0.040 (0.739)	0.375* (0.058)	0.098* (0.071)	0.209** (0.020)
Intense competition (index)	-0.138 (0.154)	-0.508*** (0.000)	-0.306*** (0.000)	-0.406*** (0.000)
No. of observations	974	531	4,399	2,145

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

When evaluating the use of secrecy and patenting (rather than effectiveness, as in Table 6), we do not find any significant impact on profitability, neither for single innovators nor for all innovators. When examining the relative importance of secrecy over patenting, secrecy seems more likely to enable a firm to achieve a high profit margin. Both for single innovators and for all innovators, the difference in the importance rating of secrecy and patenting is positive and statistically significant when looking at the profit level in the year following the introduction of an innovation (Table 19). This would imply that the technological monopoly granted by a patent is not strong enough to overcome the knowledge outflow resulting from disclosing key technological features of the inventions underlying an innovation during patenting. This result is in some contrast to papers that found a positive impact of patenting on the financial performance of firms (Czarnitzki and Kraft, 2010). One explanation for this difference is the different sample structure. Whilst we look only at a rather homogenous sample of firms that consists only of businesses that were recently able to introduce an innovation, Czarnitzki and Kraft (2010) investigate a sample of all types of firms, both innovators and non-innovators. In addition, we control for trade marks which do have a significant positive impact on profitability.

5. Conclusion

This paper investigated the determinants and outcomes of firms' decisions to protect their innovations though trade secrets and patents. We looked particularly at the role played by a combined protection strategy, i.e. using secrecy and patenting simultaneously as a protection strategy for a single innovation. In order to overcome the assignment problem common to firm-level innovation surveys, whereby one usually does not know whether firms employing both protection methods use them for one and the same innovation, or for different innovations, we have used unique information on the number of completed innovation projects gained from the German innovation survey. By focussing on firms with a single innovation we were able to establish the drivers for using both secrecy and patenting to protect an innovation, and the performance effect of this strategy with respect to innovation output and profitability, compared to that seen when only one, or none, of the two methods are implemented. The empirical analysis rests on two survey waves of the German innovation survey (reference years 2010 and 2012), with a total of 1,246 observations on firms with a single (product or process) innovation.

We find that firms combine secrecy and patenting when the strength of patent protection in their sector is high, when technological uncertainty is high and when their innovation has a higher degree of novelty and requires significant financial investment. In addition, innovators that co-operate with research bodies (universities and other research organisations) are more likely to rely on both secrecy and patenting. Young firms, as well as larger firms have a higher propensity to follow this protection strategy. Based on our data, financing constraints do not significantly affect the choice made between secrecy and patenting.

The more frequent method of combining trade secrets and patents in order to protect the new-to-market innovations of single innovators, translates into higher sales with this type of innovation when compared with other protection strategies. While single innovators with new-to-market innovations are also more likely to only use patents, but not secrecy as protection strategy, this strategy leads to higher sales only in the short run while a combined strategy seems to produce a longer lasting increase in innovation output. With respect to firm profitability, combining secrecy and patenting does not yield higher profit margins. We rather find a weakly significant positive effect for single innovators that rely only on secrecy.

When comparing the determinants for the choice of either secrecy or patenting as a protection strategy we find rather few differences. Both secrecy and patenting tend to play a more important role as the level of innovation increases, where patent protection is stronger and if technological uncertainty is high. The main difference relates to process innovators who are more likely to rely on secrecy rather than patenting. While both protection methods trigger innovation output (compared to innovators using neither of the two instruments), secrecy is more effective with respect to obtaining higher cost reductions from process innovation, whilst patenting is more effective for new-to-market innovations. Firm profitability tends to be higher for innovators relying on secrecy, while patenting does not show a significant impact on the profitability of innovators.

One main shortcoming of this research is the lack of panel data analysis. Whilst we had two survey waves containing information on protection strategies at hand, and were able to use one year lags for the impact of protection strategies on innovation output and firm profitability, no real panel data analysis could be performed. Although we were able to identify firms with a single innovation and hence overcome, to some extent, the notorious assignment problem of firm-level studies on the use of secrecy and patenting, the sample of single innovators may be a biased sample and may not be representative for the entire group of innovating firms. Panel data and information on innovation-specific protection strategies of multiple innovators would be extremely helpful to widen our understanding of the role of secrecy and patenting for increasing the returns to innovation.

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7. Appendix

Questions on protection methods in the 2010 and 2012 German Innovation Surveys

a) 2010

14.1 Which of the following measures did your enterprise use to protect its intellectual property during 2008 to 2010, and how important have they been?

	Yes	No	Importance: high	medium	low
Formal measures					
Applying for patents	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Applying for utility patents	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Registering of industrial designs	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Registering of trademarks	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Copyright	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Strategic measures					
Secrecy	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Complex design of goods or services	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3
Lead time advantage over competitors	☐ 1	☐ 2	☐ 1	☐ 2	☐ 3

b) 2012

11.1 How effective were the following protection methods for maintaining or increasing the competitiveness of product and process innovations introduced during 2010 to 2012?

Please mark one X for each line!	Degree of **Effectiveness**: *High*	*Medium*	*Low*	*Not used*
Patents	☐ 1	☐ 2	☐ 3	☐ 4
Utility Patents	☐ 1	☐ 2	☐ 3	☐ 4
Design registration	☐ 1	☐ 2	☐ 3	☐ 4
Trade marks	☐ 1	☐ 2	☐ 3	☐ 4
Copyright	☐ 1	☐ 2	☐ 3	☐ 4
Lead time advantage over competitors	☐ 1	☐ 2	☐ 3	☐ 4
Complex design of goods / services	☐ 1	☐ 2	☐ 3	☐ 4
Secrecy (incl. include non-disclosure agreements)	☐ 1	☐ 2	☐ 3	☐ 4

Table 7: Descriptive statistics for single innovators, multiple innovators and all innovators

	Single innovators	Multiple innovators	Sig.[1)]	All innovators
Age (years)	27.6	33.2	**	32.0
Size (# employees)	487.2	607.2	-	581.7
High technological uncertainty (%)	4.01	4.19	-	4.15
Large number of competitors (%)	22.8	22.2	-	22.3
Small number of competitors (%)	42.3	41.4	-	41.6
New-to-market innovation (%)	29.9	36.8	**	35.4
Innovation intensity (1,000 € per employee)	17.8	19.6	-	19.1
Process innovator (%)	52.1	63.8	**	61.3
Cooperation with businesses (%)	23.1	26.3	*	25.6
Cooperation with research (%)	31.0	31.4	-	31.3
Credit rating (index)	3.77	3.84	**	3.83
Sales share, new-to-market innovations (%)	5.49	5.64	-	5.61
Sales share, new-to-firm innovations (%)	12.5	16.2	**	15.4
Share of cost reduction from process inn. (%)	2.00	2.72	**	2.56
Profit margin (categorial 1 to 9)	5.61	5.70	-	5.68
Continuous R&D (%)	38.9	48.9	**	46.8
Capital intensity (1,000 € per employee)	118.4	166.2	-	155.7
Distribution by sector			**	
Food	3.1	4.7		4.3
Textiles	3.5	3.1		3.2
Wood/Paper	3.3	3.0		3.1
Chemicals	4.2	5.5		5.2
Plastics	2.8	3.5		3.3
Glass/Ceramics	2.0	2.4		2.3
Metals	6.5	6.9		6.9
Machinery	9.0	10.5		10.2
Electronics	10.2	11.3		11.1
Vehicles	2.2	3.8		3.5
Consumer Products	3.3	3.8		3.7
Utilities	6.7	4.9		5.2
Trade/Transport	12.3	10.6		10.9
IT Services	8.9	7.3		7.7
Financial/Professional Services	22.1	18.6		19.4

1) ** / *: difference between single and multiple innovators significant at the 1% / 5% level.

Table 8: Descriptive statistics for the protection method decision models

	Firms with a single innovation				All innovators			
	Mean	St.dev.	Min	Max	Mean	St.dev.	Min	Max
Dependent variables								
Neither secrecy nor patenting (D)	0.29	0.46	0	1	0.26	0.44	0	1
Only patenting (D)	0.05	0.21	0	1	0.05	0.21	0	1
Only secrecy (D)	0.27	0.45	0	1	0.24	0.43	0	1
Both patenting and secrecy (D)	0.39	0.49	0	1	0.45	0.50	0	1
Effectiveness of secrecy (Likert)	1.44	1.22	0	3	1.56	1.23	0	3
Effectiveness of patenting (Likert)	0.92	1.18	0	3	1.07	1.22	0	3
Use of secrecy (D)	0.66	0.47	0	1	0.69	0.46	0	1
Use of patenting (D)	0.43	0.50	0	1	0.50	0.50	0	1
Secrecy highly important (D)	0.28	0.45	0	1	0.32	0.47	0	1
Patenting highly important (D)	0.18	0.38	0	1	0.21	0.41	0	1
Relative importance of secrecy (index)	0.53	1.31	-3	3	0.49	1.32	-3	3
Both secrecy and patenting important (D)	0.22	0.42	0	1	0.28	0.45	0	1
Secrecy dominating (D)	0.35	0.48	0	1	0.32	0.46	0	1
Patenting dominating (D)	0.09	0.29	0	1	0.09	0.29	0	1
Independent variables								
Share of innovators with patents	0.35	0.18	0.0	1	0.37	0.20	0	1
Share of out-licensed patents	0.64	1.66	0.00	12.56	0.52	1.39	0.00	12.56
High technological uncertainty (D)	0.31	0.46	0	1	0.32	0.47	0	1
Large number of competitors (D)	0.23	0.42	0	1	0.22	0.42	0	1
Small number of competitors (D)	0.42	0.49	0	1	0.42	0.49	0	1
Competition has increased (D)	0.24	0.43	0	1	0.25	0.43	0	1
Market novelty (D)	0.30	0.46	0	1	0.35	0.48	0	1
Innovation intensity (log)	-4.22	2.39	-10.8	0.00	-3.62	2.47	-10.9	0.12
No innovation expenditure (D)	0.07	0.25	0	1	0.08	0.27	0	1
Process innovator (D)	0.52	0.50	0	1	0.61	0.49	0	1
Cooperation with businesses (D)	0.23	0.42	0	1	0.26	0.44	0	1
Cooperation with research (D)	0.31	0.46	0	1	0.31	0.46	0	1
Credit rating (lagged)	3.77	0.77	0	6	3.83	0.70	0	6
High profit margin (lagged)	0.27	0.45	0	1	0.26	0.44	0	1
Low profit margin (lagged)	0.14	0.35	0	1	0.13	0.33	0	1
Age (log # years)	2.87	0.96	-0.69	6.15	2.98	1.01	-0.69	6.23
Size (log # employees)	3.33	1.37	0.92	12.86	3.91	1.71	0.00	12.86
No. of observations	1,246				5,857			

D: dummy variable

Table 9: Descriptive statistics for the innovation output models [2]

	Firms with a single innovation				All innovators			
	Mean	St.dev.	Min	Max	Mean	St.dev.	Min	Max
Dependent variables								
New-to-market innovations (log)	-4.99	3.02	-6.91	5.14	-4.27	3.69	-6.91	9.38
Only new-to-firm innovations (log)	-2.94	3.46	-6.91	8.37	-1.70	3.85	-6.91	10.48
Cost reduction from process inn. (log)	-5.59	2.71	-6.91	6.06	-4.79	3.47	-6.91	9.47
Independent variables, secrecy/patenting								
Only patenting (D)	0.40	0.49	0	1	0.45	0.50	0	1
Only secrecy (D)	0.27	0.44	0	1	0.25	0.43	0	1
Both patenting and secrecy (D)	0.40	0.49	0	1	0.45	0.50	0	1
Secrecy, low effectiveness (D)	0.16	0.37	0	1	0.15	0.35	0	1
Secrecy, medium effectiveness (D)	0.23	0.42	0	1	0.23	0.42	0	1
Secrecy, high effectiveness (D)	0.27	0.45	0	1	0.31	0.46	0	1
Patenting, low effectiveness (D)	0.13	0.33	0	1	0.13	0.34	0	1
Patenting, medium effectiveness (D)	0.13	0.34	0	1	0.15	0.36	0	1
Patenting, high effectiveness (D)	0.18	0.39	0	1	0.21	0.40	0	1
Relative importance of secrecy (index)	0.51	1.29	-3	3	0.49	1.32	-3	3
Independent variables, others	3.29	1.33	0.92	9.07	3.81	1.62	0.92	11.61
Size (log # employees)	2.86	0.97	-0.69	6.15	2.97	1.00	-0.69	6.23
Age (log # years)	-4.26	2.31	-10.81	0.00	-3.77	2.39	-10.93	0.00
Innovation intensity (log)	0.06	0.23	0	1	0.08	0.27	0	1
No innovation expenditure (D)	0.40	0.49	0	1	0.46	0.50	0	1
Continuous R&D (D)	-4.99	3.02	-6.91	5.14	-4.27	3.69	-6.91	9.38
No. of observations	1,033				4,662			

D: dummy variable

Table 10: Descriptive statistics for the firm profitability models [3]

	Firms with a single innovation				All innovators			
	Mean	St.dev.	Min	Max	Mean	St.dev.	Min	Max
Dependent variables								
Profit margin (categorial)	4.84	5.21	-5	15	4.96	5.16	-5	15
Independent variables, secrecy/patenting								
Only patenting highly effective (D)	0.08	0.27	0	1	0.09	0.29	0	1
Only secrecy highly effective (D)	0.18	0.39	0	1	0.20	0.40	0	1
Both patenting and secrecy highly effective (D)	0.10	0.30	0	1	0.12	0.32	0	1
Secrecy, high effectiveness (D)	0.28	0.45	0	1	0.32	0.47	0	1
Patenting, low effectiveness (D)	0.18	0.38	0	1	0.21	0.41	0	1
Only patenting used (D)	0.28	0.45	0	1	0.25	0.43	0	1
Only secrecy used (D)	0.04	0.20	0	1	0.05	0.21	0	1
Both patenting and secrecy used (D)	0.40	0.49	0	1	0.46	0.50	0	1
Relative importance of secrecy (index)	0.55	1.30	-3	3	0.50	1.32	-3	3
Independent variables, others								
Valid trade marks (D)	0.13	0.33	0	1	0.22	0.42	0	1
Size (log # employees)	3.38	1.34	1.10	9.07	3.94	1.67	0.00	11.66
Age (log # years)	2.90	0.93	-0.69	6.15	2.99	0.99	-0.69	6.23
Market novelty (D)	0.30	0.46	0	1	0.37	0.48	0	1
Product imitation (D)	0.42	0.49	0	1	0.42	0.49	0	1
Process innovation (D)	0.52	0.50	0	1	0.62	0.48	0	1
Capital intensity (€ per employee, log)	-2.76	2.49	-15.91	1.46	-2.59	2.47	-18.26	1.88
Competition intensity (index)	5.79	2.34	0	12	5.94	2.31	0	12
No. of observations	974				4,399			

D: dummy variable

Table 11: Determinants of using secrecy and patenting for protecting a firm's innovation / IP: results of bivariate probit models (estimated coefficients, significance levels in brackets)

		Firms with a single innovation		All innovators	
		Use of secrecy[1)]	Use of patenting[1)]	Use of secrecy[1)]	Use of patenting[1)]
Strength of IP Law	Share of innovators with patents	0.375 (0.180)	1.069*** (0.000)	0.764*** (0.000)	1.405*** (0.000)
	Share of out-licensed patents	0.019 (0.511)	0.000 (0.998)	0.023 (0.141)	0.005 (0.734)
Degree of innovation competition	High technological uncertainty (D)[a)]	0.388*** (0.000)	0.218** (0.011)	0.138*** (0.001)	0.098** (0.013)
	Large no. of competitors (D)[a)]	-0.167 (0.118)	-0.189* (0.083)	0.053 (0.297)	-0.042 (0.409)
	Small number of competitors (D)[a)]	-0.137 (0.148)	-0.011 (0.903)	0.024 (0.586)	0.051 (0.232)
	Competition has increased (D)[a)]	-0.062 (0.527)	-0.036 (0.708)	0.069 (0.126)	0.038 (0.387)
Level of innovation	Market novelty (D)[a)]	0.312*** (0.001)	0.498*** (0.000)	0.337*** (0.000)	0.450*** (0.000)
	Innovation intensity (log)[a)]	0.120*** (0.000)	0.113*** (0.000)	0.098*** (0.000)	0.087*** (0.000)
	No innovation expenditure (D)	-0.934*** (0.000)	-0.988*** (0.000)	-0.963*** (0.000)	-0.816*** (0.000)
Type of innovation	Process innovator (D)	-0.058 (0.481)	-0.141* (0.079)	0.027 (0.500)	-0.042 (0.274)
Open innovation practice	Cooperation with businesses (D)[a)]	0.034 (0.771)	0.112 (0.295)	0.091 (0.112)	0.011 (0.830)
	Cooperation with research (D)[a)]	0.250** (0.019)	0.309*** (0.002)	0.294*** (0.000)	0.387*** (0.000)
Financial constraints	Credit rating (index, lagged)	-0.039 (0.473)	-0.033 (0.524)	-0.019 (0.480)	-0.028 (0.296)
	High profit margin (lagged)[a)]	0.055 (0.586)	0.027 (0.779)	0.060 (0.213)	0.020 (0.664)
	Low profit margin (lagged)[a)]	0.032 (0.789)	0.062 (0.617)	0.023 (0.704)	0.025 (0.670)
Controls	Age (log # years)	-0.143*** (0.001)	-0.125*** (0.005)	-0.090*** (0.000)	-0.047** (0.014)
	Size (log # employees)	0.075** (0.021)	0.156*** (0.000)	0.089*** (0.000)	0.166*** (0.000)
Applies to (no. of observations)		823	541	4,043	2,906
No. of observations (total)		1,246	1,246	5,857	5,857

1) Secrecy or patenting of low, medium or high effectiveness.

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 12: Determinants of secrecy and patenting being highly important for protecting a firm's innovation / IP: results of bivariate probit models (estimated coefficients, significance levels in brackets)

		Firms with a single innovation		All innovators	
		Secrecy highly important	Patenting highly important	Secrecy highly important	Patenting highly important
Strength of IP Law	Share of innovators with patents	0.465* (0.097)	0.972*** (0.000)	0.545*** (0.000)	0.926*** (0.000)
	Share of out-licensed patents	0.034 (0.204)	0.026 (0.380)	0.038** (0.011)	0.043** (0.017)
Degree of innovation competition	High technological uncertainty (D)[a)]	0.130 (0.148)	0.168* (0.080)	0.048 (0.223)	0.057 (0.196)
	Large no. of competitors (D)[a)]	-0.368*** (0.002)	-0.266** (0.043)	-0.036 (0.475)	-0.181*** (0.003)
	Small number of competitors (D)[a)]	-0.048 (0.609)	-0.062 (0.547)	0.004 (0.923)	0.078* (0.092)
	Competition has increased (D)[a)]	-0.028 (0.779)	-0.043 (0.705)	0.084* (0.055)	0.038 (0.446)
Level of innovation	Market novelty (D)[a)]	0.193** (0.036)	0.330*** (0.001)	0.244*** (0.000)	0.308*** (0.000)
	Innovation intensity (log)[a)]	0.047 (0.150)	0.093*** (0.007)	0.073*** (0.000)	0.096*** (0.000)
	No innovation expenditure (D)	-0.593** (0.022)	-0.535** (0.048)	-0.618*** (0.000)	-0.669*** (0.000)
Type of innovation	Process innovator (D)	0.082 (0.325)	-0.171* (0.066)	0.099*** (0.010)	-0.068 (0.118)
Open innovation practice	Cooperation with businesses (D)[a)]	0.129 (0.229)	0.258** (0.020)	0.027 (0.584)	-0.010 (0.855)
	Cooperation with research (D)[a)]	0.319*** (0.002)	0.063 (0.564)	0.293*** (0.000)	0.305*** (0.000)
Financial constraints	Credit rating (index, lagged)	-0.075 (0.177)	-0.016 (0.793)	-0.055** (0.042)	-0.020 (0.511)
	High profit margin (lagged)[a)]	0.453*** (0.000)	0.100 (0.373)	0.101** (0.030)	0.102* (0.051)
	Low profit margin (lagged)[a)]	0.043 (0.736)	0.155 (0.264)	0.019 (0.741)	0.132** (0.041)
Controls	Age (log # years)	-0.104** (0.025)	-0.038 (0.451)	-0.107*** (0.000)	-0.044** (0.041)
	Size (log # employees)	0.032 (0.362)	0.135*** (0.000)	0.062*** (0.000)	0.171*** (0.000)
Applies to (no. of observations)		347	220	1,880	1,232
No. of observations (total)		1,246	1,246	5,857	5,857

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 13: Determinants of the effectiveness of secrecy and patenting for protecting a firm's innovation / IP: results of ordered probit models (estimated coefficients, significance levels in brackets)

		Firms with a single innovation		All innovators	
		Effectiveness of secrecy[1)]	Effectiveness of patenting[1]	Effectiveness of secrecy[1)]	Effectiveness of patenting[1]
Strength of IP Law	Share of innovators with patents	0.396* (0.086)	0.986*** (0.000)	0.597*** (0.000)	1.190*** (0.000)
	Share of out-licensed patents	0.031 (0.188)	0.011 (0.679)	0.035*** (0.008)	0.021 (0.145)
Degree of innovation competition	High technological uncertainty (D)[a)]	0.252*** (0.000)	0.178** (0.020)	0.093*** (0.004)	0.076** (0.026)
	Large no. of competitors (D)[a)]	-0.226*** (0.008)	-0.199** (0.043)	0.018 (0.653)	-0.073 (0.102)
	Small number of competitors (D)[a)]	-0.095 (0.227)	-0.024 (0.770)	0.009 (0.800)	0.072* (0.051)
	Competition has increased (D)[a)]	-0.054 (0.501)	-0.038 (0.668)	0.062* (0.084)	0.028 (0.457)
Level of innovation	Market novelty (D)[a)]	0.243*** (0.001)	0.409*** (0.000)	0.280*** (0.000)	0.373*** (0.000)
	Innovation intensity (log)[a)]	0.083*** (0.001)	0.108*** (0.000)	0.079*** (0.000)	0.094*** (0.000)
	No innovation expenditure (D)	-0.764*** (0.000)	-0.836*** (0.000)	-0.797*** (0.000)	-0.801*** (0.000)
Type of innovation	Process innovator (D)	0.019 (0.780)	-0.157** (0.031)	0.063** (0.046)	-0.070** (0.038)
Open innovation practice	Cooperation with businesses (D)[a)]	0.106 (0.251)	0.168* (0.063)	0.061 (0.142)	0.010 (0.809)
	Cooperation with research (D)[a)]	0.239*** (0.005)	0.216** (0.011)	0.275*** (0.000)	0.344*** (0.000)
Financial constraints	Credit rating (index, lagged)	-0.061 (0.146)	-0.018 (0.685)	-0.044** (0.045)	-0.023 (0.334)
	High profit margin (lagged)[a)]	0.218*** (0.009)	0.053 (0.547)	0.072* (0.057)	0.056 (0.164)
	Low profit margin (lagged)[a)]	0.040 (0.677)	0.082 (0.457)	0.024 (0.619)	0.075 (0.136)
Controls	Age (log # years)	-0.122*** (0.001)	-0.101** (0.011)	-0.099*** (0.000)	-0.053*** (0.002)
	Size (log # employees)	0.057** (0.040)	0.161*** (0.000)	0.074*** (0.000)	0.174*** (0.000)
No. of observations		1,246	1,246	5,857	5,857

1) measured on a 4-point Likert scale: not used, low, medium, high effectiveness.

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 14: Determinants of the relative importance of secrecy over patenting for protecting a firm's innovation / IP: results of ordered probit models (estimated coefficients, significance levels in brackets)

		Firms with a single innovation		All innovators	
		Including firms neither using secrecy nor patenting	Excluding firms neither using secrecy nor patenting	Including firms neither using secrecy nor patenting	Excluding firms neither using secrecy nor patenting
Strength of IP Law	Share of innovators with patents	-0.444** (0.043)	-0.646*** (0.009)	-0.385*** (0.000)	-0.699*** (0.000)
	Share of out-licensed patents	0.023 (0.230)	0.019 (0.435)	0.018 (0.117)	0.014 (0.313)
Degree of innovation competition	High technological uncertainty (D)[a)]	0.069 (0.301)	-0.014 (0.853)	0.019 (0.528)	-0.006 (0.849)
	Large no. of competitors (D)[a)]	-0.056 (0.489)	-0.042 (0.659)	0.077** (0.043)	0.086* (0.057)
	Small number of competitors (D)[a)]	-0.092 (0.222)	-0.063 (0.465)	-0.048 (0.162)	-0.043 (0.255)
	Competition has increased (D)[a)]	-0.000 (0.997)	-0.012 (0.896)	0.022 (0.514)	0.024 (0.527)
Level of innovation	Market novelty (D)[a)]	-0.125* (0.099)	-0.247*** (0.002)	-0.061* (0.068)	-0.152*** (0.000)
	Innovation intensity (log)[a)]	-0.011 (0.643)	-0.043 (0.119)	-0.004 (0.705)	-0.018 (0.161)
	No innovation expenditure (D)	-0.093 (0.592)	0.185 (0.423)	-0.129* (0.097)	0.093 (0.368)
Type of innovation	Process innovator (D)	0.122* (0.051)	0.162** (0.029)	0.096*** (0.001)	0.121*** (0.000)
Open innovation practice	Cooperation with businesses (D)[a)]	-0.043 (0.639)	-0.067 (0.501)	0.051 (0.225)	0.031 (0.475)
	Cooperation with research (D)[a)]	0.023 (0.788)	-0.039 (0.678)	-0.065 (0.109)	-0.115*** (0.007)
Financial constraints	Credit rating (index, lagged)	-0.044 (0.264)	-0.017 (0.664)	-0.019 (0.340)	-0.013 (0.587)
	High profit margin (lagged)[a)]	0.114 (0.129)	0.179** (0.038)	0.004 (0.910)	0.023 (0.559)
	Low profit margin (lagged)[a)]	-0.022 (0.817)	-0.010 (0.928)	-0.047 (0.313)	-0.062 (0.241)
Controls	Age (log # years)	-0.039 (0.221)	0.019 (0.640)	-0.043*** (0.003)	-0.020 (0.240)
	Size (log # employees)	-0.073*** (0.005)	-0.105*** (0.000)	-0.073*** (0.000)	-0.097*** (0.000)
No. of observations (total)		1,246	880	5,857	4,314

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 15: Determinants of the combined importance of secrecy and patenting to protect a firm's innovations / IP: results of probit models (estimated coefficients, significance levels in brackets)

		Firms with a single innovation			All innovators		
		Both secrecy and patenting[1)]	Secrecy dominating[2)]	Patenting dominating[3)]	Both secrecy and patenting[1)]	Secrecy dominating[2)]	Patenting dominating[3)]
Strength of IP Law	Share of innovators with patents	0.919*** (0.001)	-0.508* (0.051)	0.508 (0.168)	0.830*** (0.000)	-0.317*** (0.005)	0.681*** (0.000)
	Share of out-licensed patents	0.035 (0.228)	0.008 (0.749)	-0.105* (0.083)	0.037** (0.022)	0.007 (0.648)	-0.023 (0.308)
Degree of innovation competition	High technological uncertainty (D)[a)]	0.202** (0.033)	0.140* (0.093)	-0.046 (0.697)	0.078* (0.063)	0.034 (0.373)	-0.019 (0.707)
	Large no. of competitors (D)[a)]	-0.123 (0.326)	-0.095 (0.361)	-0.067 (0.670)	0.036 (0.525)	0.029 (0.543)	-0.241*** (0.001)
	Small number of competitors (D)[a)]	0.045 (0.653)	-0.184** (0.042)	0.033 (0.790)	0.160*** (0.000)	-0.120*** (0.004)	-0.116** (0.032)
	Competition has increased (D)[a)]	-0.159 (0.145)	0.010 (0.918)	0.121 (0.368)	0.036 (0.446)	-0.009 (0.839)	-0.027 (0.644)
Level of innovation	Market novelty (D)[a)]	0.216** (0.024)	0.029 (0.745)	0.449*** (0.000)	0.281*** (0.000)	0.017 (0.668)	0.241*** (0.000)
	Innovation intensity (log)[a)]	0.143*** (0.000)	-0.001 (0.973)	0.010 (0.785)	0.130*** (0.000)	-0.030** (0.039)	-0.029 (0.125)
	No innovation expenditure (D)	-1.154*** (0.000)	-0.266 (0.247)	0.039 (0.895)	-0.919*** (0.000)	-0.197* (0.057)	0.027 (0.853)
Type of innovation	Process innovator (D)	-0.095 (0.296)	0.078 (0.319)	-0.169 (0.126)	-0.065 (0.116)	0.073* (0.051)	-0.146*** (0.004)
Open innovation practice	Cooperation with businesses (D)[a)]	0.194* (0.071)	-0.092 (0.386)	-0.024 (0.873)	0.079 (0.121)	0.046 (0.362)	-0.096 (0.159)
	Cooperation with research (D)[a)]	0.196* (0.063)	-0.067 (0.495)	0.079 (0.569)	0.363*** (0.000)	-0.154*** (0.002)	0.045 (0.489)
Financial constraints	Credit rating (index, lagged)	0.013 (0.828)	-0.076 (0.136)	-0.015 (0.846)	-0.038 (0.189)	-0.017 (0.505)	0.027 (0.438)
	High profit margin (lagged)[a)]	0.204* (0.056)	-0.054 (0.576)	-0.148 (0.292)	0.114** (0.021)	-0.057 (0.204)	-0.036 (0.562)
	Low profit margin (lagged)[a)]	0.099 (0.465)	-0.062 (0.603)	-0.001 (0.993)	0.024 (0.703)	-0.036 (0.530)	0.176** (0.017)
Controls	Age (log # years)	-0.162*** (0.001)	-0.031 (0.468)	0.081 (0.194)	-0.086*** (0.000)	-0.026 (0.160)	0.026 (0.298)
	Size (log # employees)	0.186*** (0.000)	-0.078** (0.018)	0.028 (0.519)	0.198*** (0.000)	-0.108*** (0.000)	0.029* (0.065)
Applies to (no. of observations)		280	436	113	1,649	1,846	548
No. of observations (total)		1,246	1,246	1,246	5,857	5,857	5,857

1) Both patenting and secrecy are of medium or high importance. 2) Secrecy is of higher importance than patenting, and patenting is neither of high nor medium importance. 3) Patenting is of higher importance than secrecy, and secrecy is neither of high nor medium importance.

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 16: The impact of secrecy and patenting effectiveness on innovation success: results of OLS models (estimated coefficients, significance levels in brackets)

	Firms with a single innovation						All innovators					
	New-to-market innovations		Only new-to-firm innovations		Cost reductions owing to process innovations		New-to-market innovations		Only new-to-firm innovations		Cost reductions owing to process innovations	
	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag
Secrecy, low effectiveness (D)	0.183	1.266**	0.506	0.329	-0.004	0.562	0.268*	0.392	0.229	0.864***	0.156	1.018***
	(0.507)	(0.013)	(0.143)	(0.564)	(0.986)	(0.301)	(0.086)	(0.146)	(0.205)	(0.003)	(0.319)	(0.002)
Secrecy, medium effectiveness (D)	-0.096	-0.157	0.517*	0.390	-0.124	0.122	0.276*	-0.005	0.336**	0.555**	0.148	0.698**
	(0.704)	(0.706)	(0.095)	(0.451)	(0.613)	(0.808)	(0.054)	(0.985)	(0.034)	(0.033)	(0.295)	(0.016)
Secrecy, high effectiveness (D)	0.257	0.400	0.451	0.422	0.329	0.577	0.605***	0.141	0.352**	0.697***	0.432***	0.937***
	(0.362)	(0.319)	(0.153)	(0.418)	(0.193)	(0.265)	(0.000)	(0.546)	(0.020)	(0.006)	(0.002)	(0.001)
Patenting, low effectiveness (D)	0.734**	0.565	-0.582*	-0.983*	-0.043	-0.731	0.557***	0.346	0.065	-0.230	0.074	-0.142
	(0.013)	(0.238)	(0.092)	(0.079)	(0.867)	(0.153)	(0.000)	(0.163)	(0.694)	(0.386)	(0.624)	(0.644)
Patenting, medium effectiveness (D)	1.145***	0.734	0.275	0.423	-0.152	1.702***	0.899***	0.608**	0.207	0.217	-0.253*	0.183
	(0.001)	(0.143)	(0.415)	(0.439)	(0.576)	(0.005)	(0.000)	(0.019)	(0.195)	(0.397)	(0.091)	(0.579)
Patenting, high effectiveness (D)	0.996***	1.153**	-0.203	0.010	-0.576**	-0.144	1.343***	1.119***	-0.010	0.076	0.084	0.379
	(0.001)	(0.024)	(0.545)	(0.985)	(0.020)	(0.801)	(0.000)	(0.000)	(0.953)	(0.758)	(0.579)	(0.244)
Size (log # employees)	0.119	0.151	0.348***	0.776***	0.471***	0.533***	0.441***	0.526***	0.750***	0.965***	0.693***	0.835***
	(0.152)	(0.248)	(0.002)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age (log # years)	0.128	0.235	0.041	0.045	0.008	0.054	0.018	-0.118	0.084	0.254***	-0.094*	-0.008
	(0.184)	(0.180)	(0.750)	(0.835)	(0.937)	(0.778)	(0.735)	(0.227)	(0.154)	(0.006)	(0.074)	(0.939)
Innovation intensity (log)[a)]	0.242***	0.271**	0.207**	0.286*	0.129*	0.285**	0.297***	0.272***	0.262***	0.295***	0.202***	0.358***
	(0.001)	(0.016)	(0.022)	(0.061)	(0.061)	(0.046)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
No innovation expenditure (D)	-1.830***	-1.985**	-1.319*	-3.685***	-0.727	-2.681***	-2.042***	-2.285***	-1.127***	-2.884***	-1.672***	-2.551***
	(0.000)	(0.015)	(0.058)	(0.000)	(0.157)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Continuous R&D (D)[a)]	0.948***	1.562***	-0.389	1.244***	0.528***	0.244	1.093***	1.118***	0.466***	1.416***	0.252**	0.739***
	(0.000)	(0.000)	(0.132)	(0.010)	(0.009)	(0.597)	(0.000)	(0.000)	(0.000)	(0.000)	(0.031)	(0.004)
No. of observations	1,033	363	1,033	360	1,033	257	4,662	1,676	4,662	1,648	4,662	1,229

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable. a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 17: The impact of the relative difference of secrecy over patenting effectiveness on innovation success: results of OLS models (estimated coefficients, significance levels in brackets)

	Firms with a single innovation						All innovators					
	New-to-market innovations		Only new-to-firm innovations		Cost reductions owing to process innovations		New-to-market innovations		Only new-to-firm innovations		Cost reductions owing to process innovations	
	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag	No lag	1 year lag
Relative importance of secrecy over patenting (index)	-0.148*	-0.196	0.080	0.007	0.125*	-0.009	-0.103***	-0.168***	0.056	0.067	0.073**	0.091
	(0.056)	(0.113)	(0.326)	(0.960)	(0.051)	(0.954)	(0.009)	(0.010)	(0.164)	(0.286)	(0.049)	(0.242)
Size (log # employees)	0.151*	0.178	0.362***	0.811***	0.454***	0.525***	0.517***	0.575***	0.766***	0.998***	0.708***	0.895***
	(0.070)	(0.188)	(0.001)	(0.000)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age (log # years)	0.082	0.212	0.033	0.042	0.013	0.017	-0.026	-0.141	0.074	0.238**	-0.102*	-0.037
	(0.399)	(0.241)	(0.796)	(0.847)	(0.887)	(0.928)	(0.621)	(0.150)	(0.206)	(0.010)	(0.054)	(0.723)
Innovation intensity (log)[a)]	0.298***	0.308***	0.229***	0.308**	0.115*	0.326**	0.367***	0.316***	0.277***	0.325***	0.216***	0.417***
	(0.000)	(0.005)	(0.009)	(0.044)	(0.081)	(0.022)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
No innovation expenditure (D)	-2.279***	-2.328***	-1.443**	-3.827***	-0.645	-2.840***	-2.600***	-2.655***	-1.262***	-3.158***	-1.776***	-3.007***
	(0.000)	(0.003)	(0.034)	(0.000)	(0.199)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Continuous R&D (D)[a)]	1.138***	1.834***	-0.318	1.352***	0.505**	0.632	1.380***	1.281***	0.528***	1.510***	0.311***	0.908***
	(0.000)	(0.000)	(0.206)	(0.004)	(0.012)	(0.168)	(0.000)	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)
No. of observations	1,033	363	1,033	360	1,033	257	4,662	1,676	4,662	1,648	4,662	1,229

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 18: Impact of using secrecy and patenting on firm profitability: results of interval regression models (estimated coefficients, significance levels in brackets)

	Firms with a single innovation		All innovators	
	No lag	1 year lag	No lag	1 year lag
Use of secrecy only (D)	-0.603 (0.320)	1.210 (0.142)	-0.180 (0.545)	0.758* (0.062)
Use of patenting only (D)	-0.899 (0.438)	1.619 (0.293)	-0.554 (0.287)	-0.545 (0.440)
Use of both secrecy and patenting (D)	-0.215 (0.716)	-0.221 (0.779)	0.100 (0.726)	0.364 (0.347)
Valid trade marks (D)	1.191* (0.086)	1.684* (0.080)	0.548* (0.051)	0.988*** (0.009)
Size (log # employees)	-0.509*** (0.006)	-0.339 (0.163)	-0.151** (0.041)	-0.403*** (0.000)
Age (log # years)	0.100 (0.689)	0.418 (0.220)	0.186* (0.089)	0.403*** (0.010)
Market novelty (D)	0.259 (0.700)	-0.177 (0.841)	0.037 (0.904)	0.554 (0.188)
Product imitation (D)	0.042 (0.945)	0.281 (0.732)	-0.107 (0.711)	0.283 (0.476)
Process innovation (D)	1.039** (0.037)	1.436** (0.035)	0.544** (0.016)	1.006*** (0.001)
Capital intensity (€ per employee, log)[a)]	-0.048 (0.690)	0.448** (0.024)	0.098* (0.071)	0.252*** (0.004)
Intense competition (index)	-0.144 (0.138)	-0.515*** (0.000)	-0.307*** (0.000)	-0.420*** (0.000)
No. of observations	974	531	4,399	2,265

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.

Table 19: Impact of the relative difference in the effectiveness of secrecy and patenting on firm profitability: results of interval regression models (estimated coefficients, significance levels in brackets)

	Firms with a single innovation		All innovators	
	No lag	1 year lag	No lag	1 year lag
Relative importance of secrecy over patenting (index)	0.069 (0.694)	0.407* (0.091)	0.045 (0.571)	0.289*** (0.008)
Valid trade marks (D)	1.160* (0.094)	1.903** (0.047)	0.577** (0.038)	1.045*** (0.006)
Size (log # employees)	-0.500*** (0.006)	-0.326 (0.182)	-0.141* (0.056)	-0.383*** (0.000)
Age (log # years)	0.119 (0.633)	0.411 (0.224)	0.184* (0.091)	0.400** (0.010)
Market novelty (D)	0.196 (0.764)	-0.114 (0.893)	0.049 (0.872)	0.625 (0.129)
Product imitation (D)	-0.024 (0.968)	0.340 (0.675)	-0.115 (0.689)	0.312 (0.429)
Process innovation (D)	0.998** (0.045)	1.463** (0.032)	0.543** (0.016)	1.001*** (0.001)
Capital intensity (€ per employee, log)[a)]	-0.036 (0.767)	0.408** (0.039)	0.101* (0.063)	0.259*** (0.003)
Intense competition (index)	-0.144 (0.139)	-0.516*** (0.000)	-0.306*** (0.000)	-0.422*** (0.000)
No. of observations	974	531	4,399	2,265

*, **, ***: significant at 10%, 5%, 1% level. D: dummy variable.

a) Missing values for these variables have been set to 0 and indicators were added to indicate this data change.

All models include 15 sector dummies and an indicator for the survey wave used.