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Protecting Innovation Through Patents and Trade Secrets: Evidence for Firms with a Single Innovation

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ABSTRACT

This paper analyzes the use and effectiveness of patents and trade secrets designed to protect innovation. While previous studies have usually considered patents and trade secrets as substitutes for one another, we investigate to what extent and in what situations the two protection methods are used jointly. We identify protection strategies for single innovation firms and hence overcome the assignment problem of existing empirical studies, that is, 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, providing some evidence for a complementarity of the two protection methods.

KEY WORDS


Patents; trade secrets; single innovation; innovation output

JEL CLASSIFICATIONS

O31; O32; O34

1. Introduction

When protecting innovations through patents, firms face a trade-off between disclosing information and obtaining a temporary monopoly for commercializing 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, the ease of imitation, as well as market structure, firm capabilities, and competitor strategies (see Anton and Yao 2004; Kultti, Takalo, and Toikka 2006; 2007; Mosel 2011; Panagopoulos and Park 2015; Ottoz and Cugno 2011). Empirical studies frequently find that firms favor secrecy over patenting

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(Levin et al. 1987; Brouwer and Kleinknecht 1999; Cohen, Nelson, and Walsh 2000; Cohen et al. 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 data suggest that both protection methods are used simultaneously. This is not surprising if the two methods are employed for different innovations. But firms may also choose to use both strategies for a single innovation 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 while maintaining the option of later patenting the invention (Graham 2004).

In this paper, we empirically analyze the choice of innovating firms to protect their innovations through patenting and/or secrecy, and whether this choice affects innovative success, following an approach similar to Hall et al. (2013). Starting from propositions of theoretical models on the interaction between patenting and secrecy, we investigate a number of factors that potentially 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.

The paper contributes to the literature in two ways. First and most importantly, our study investigates the choice and impact of protection methods for firms with a single innovation. This study design overcomes a main shortcoming of most firm-level studies, which look at protection strategies at the firm level. Since firms, particularly large firms, often have several innovations at the same time, protection methods may refer to different innovations. The co-occurrence of patenting and secrecy may hence not reflect a combination of the two strategies but simply the use of different protection methods for different innovations. Second, we extend the analysis of innovation performance impacts of patenting to process innovations, while the existing literature usually focuses on product innovations only. Since process innovation is a major part of firms' innovative activities, considering performance effects of patenting and secrecy for this type of innovation extends our knowledge on the effectiveness of these protection methods.

The paper is organized as follows. In the next section, we discuss the likely determinants of patenting and/or secrecy from the theoretical and empirical literature. [Section 3](#) describes the data and presents descriptive results. [Section 4](#) contains the results of our model estimations. The main conclusions of our analysis are presented in [Section 5](#).

2. Determinants of using patents and secrecy

In a recent literature survey, Hall et al. (2014) summarized 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 discuss six main groups of determinants of patenting and secrecy as protection mechanisms for innovation that will guide our own empirical analysis. In addition, we briefly summarize other factors that may influence the choice of protection methods and discuss the findings in the literature on the combined use of patents and secrecy.

2.1. Strength of intellectual property law

An obvious determinant of the use of patenting and secrecy as protection methods is the effectiveness of patent and trade secrets legislation. Strong legislation – which means that firms can effectively prosecute infringement of their innovations – usually encourages firms to rely on legal protection. When comparing patent and trade secrets law, the former has a much narrower scope, as only inventions with an industrial application potential can be patented, whereas trade secrets can be applied to a much broader array of intellectual assets. There are hence many more opportunities to use trade secrets than patents. The theoretical and empirical literature has paid little attention to this fact, as it mostly treats the two protection methods as similarly applicable. Kultti, Takalo, and Toikka (2007), for example, demonstrate in a theoretical model 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. Png (2016) shows in a theoretical model that strong trade secrets law in terms of limiting the likelihood of reverse engineering results in less patenting particularly among incumbent firms that have a technology lead. Denicolò and Franzoni (2004) considered 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, Nanda and Steven (2015) empirically analyzed the role of the relative protection provided by patent and trade secrets law in the US. They found that the strengthening of trade secret law by US 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 (2017) studied the impact of changes in US 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 19th and in the early 20th century, Moser (2012) shows 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) looked 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 intellectual property (IP) conflict. Kwon (2012a) considered the situation of patent thickets, that is, when firms compete for multiple complementary patents. In such a case, strong patent protection will result in a decrease in the R&D investment of firms. In contrast, if firms compete over a single innovation, strong 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 was also considered by Bhattacharya and Guriev (2006), who analyzed the choice between an open sale after knowledge has been patented and a closed sale that precludes further disclosure. Contracting parties will choose the closed sale whenever the interim knowledge is more valuable and leakage is sufficiently high. The findings from the literature on the strength of IP law suggest that the use of patents and trade secrets will increase with the relative strength of the respective legislation, albeit depending on the technological and competitive environment of the firm.

2.2. Degree of innovation competition

The assumption of a sole innovator in the model of Kultti, Takalo, and Toikka (2007) is rarely found in practice. Most technological markets are characterized 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 – meaning the intensity by which firms compete over finding new technological solutions for a certain problem (e.g., a new drug to fight a certain disease) – is commonly seen as a driver for patenting. A common finding in the literature is that in the case of simultaneous invention activity, 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, Takalo, and Toikka (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 competitors will opt for strategic disclosure in order to persuade the competitor to exit the patent race. Ponce (2007) shows that an 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) investigated 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 incentive to patent, while an increase in the number of firms may cause patenting to occur earlier if the strength of patent protection is high. Summing up, a high degree of innovation competition among firms with similar technological competencies will result in

increased use of patent protection, while for firms with a clear technological lead over their competitors, secrecy will be the preferred protection method.

2.3. Level of innovation

In their seminal paper, Anton and Yao (2004) modeled the role of the degree of innovation in terms of small versus 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) used data from the French innovation survey and found – 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, Moser (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, Ceccagnoli, and Cohen (2008) show that most innovations are not worth patenting, but that for those that are, patent protection stimulates R&D. Hall et al. (2013) found that firms involved in R&D are more likely to rely on patenting than innovators who 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. Patent protection and the level of innovation can reinforce each other, as the paper by Czarnitzki and Toole (2011) shows. An effective patent protection mechanism reduces market uncertainty about future developments in the market, which positively affects R&D investment decisions.

2.4. 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 in the absence of disclosure, 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 innovations 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) analyzed the circumstances under which process innovators will opt for patenting instead of secrecy, even if secrecy is costless. They found 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-cost 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 underlying patent has expired.

2.5. Open innovation practices

The way in which firms organize the innovation process is likely to have an impact on their protection strategy. In the literature, there are two views as to how external knowledge sourcing and the choice of protection methods are linked (Arora, Athreye, and Huang 2016). The “spillover prevention” approach stresses that collaborating firms favor 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 Peukert (2015) found that firms that 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, Criscuolo and Ammon 2009; Hagedoorn and Ridder 2012). Laursen and Salter (2014) investigate the “paradox of openness.” While the creation of innovations often requires openness, their commercialization necessitates protection. They find that collaborating firms often refrain from patenting in order to stimulate collaboration with external actors. There is also some evidence that firms deliberately disclose certain knowledge to the general public (“selective revealing”) in order to spur complementary innovations (Alexy, George, and Ammon 2013; Henkel, Schöberl, and Alexy 2014). In addition, the strategic use of secrecy has been supported by the emergence of thorough secrecy management in firms (Bos, Broekhuizen, and de Faria 2015).

There are empirical results to support both views. Cassiman and Veugelers (2002), Cosh et al. (2011), Zobel, Balsmeier, and Chesbrough (2016), and Huang et al. (2014) found a positive relationship between openness and patenting. Arora, Athreye, and Huang (2016) show that patenting due to openness is higher among technologically leading firms, while firms that focus on incremental innovations are less willing to patent. Arundel (2001) found only weak evidence that participation in cooperative R&D increases the returns of a patent-based protection strategy for product innovations compared to a secrecy strategy. Laursen and Salter (2014) investigated the “paradox of openness”: while innovation often requires openness, commercialization necessitates 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 (2009) found 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, Athreye, and Huang (2016) 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. All in all, there is mixed evidence on whether openness in innovation stimulates the use of patents or secrecy as the main protection method.

2.6. Financial constraints

Applying for patents and monitoring potential infringements is costly. Firms with financial constraints may hence opt for protection methods that imply lower costs,

such as secrecy. Graham et al. (2009), as well as Cordes, Hertzfeld, and Vonortas (1999), found that cost is the most significant reason why start-ups and small high-tech firms refrain from patenting. 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). One may conclude from the literature that financially more constrained firms are more likely to refrain from using patents as a protection method and rather prefer secrecy.

2.7. Other factors

In addition to the six groups of determinants discussed above, a number of other factors can influence a firm's choice of using patents or secrecy to protect its innovations. First, firm-specific factors such as size or age, as well as management practices and a firm's competitive strategy, can affect the choice of protection method. A study by Arundel (2001), based on data from the first Community Innovation Survey, shows that for product innovations, the probability to rate patenting as more effective than secrecy increases with firm size and that an innovation strategy focused on internal sources favors secrecy. Hall et al. (2013) also found positive size effects on the propensity to patent, whereas age or the geographic market orientation showed no significant impact. Industry-specific factors such as demand preferences, market size, type of competition, and the nature of technological change can also affect the use of protection methods, as well as the macroeconomic environment and government policy, such as schemes supporting the use of patents by smaller firms. Since we do not focus on these factors in the present paper, we refrain from a more detailed discussion here.

2.8. 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 patent the invention later. Hegde, Mowery, and Graham (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 Hegde (2014) found that a small fraction of US 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) analyzed 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 exploit it usefully. Otherwise, the innovator will choose either to patent the entire innovation or to keep it secret in its entirety. Mixing patents and trade secrets was also analyzed 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 to patents due to the lack of an independent invention defense 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 redesign or replicate and some of 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. All in all, the literature on the complementarity of patents and secrecy does not provide a clear conclusion on whether combining the two protection methods is more beneficial, but rather it stresses the role of situational factors.

3. Model and data

3.1. Models

In this paper, we estimate two types of empirical models, following Hall et al. (2013): (1) the determinants of using patenting and secrecy as methods to protect a firm's innovations, and (2) the impact of patenting and secrecy on a firm's product and process innovation output. We extend the analysis previously conducted by Hall et al. (2013) by considering a larger number of potential determinants and by looking at process innovation success. Most importantly, we are able to run our analysis for a subsample 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 method (pm) to a set of variables that are intended to represent the six groups of determinants 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):

$$pm_i = a + \beta_1 ip_str_i + \beta_2 in_com_i + \beta_3 in_lev_i + \beta_4 in_typ_i + \beta_5 in_op_i + \beta_6 fi_con_i + \chi X_i + \varepsilon_i \quad (1)$$

where pm represents the use and effectiveness of patents and trade secrets. It is operationalized in different ways. The main model variant employs the four combinations of using patents and trade secrets (neither of them, both of them, only patenting, or

only secrecy). Other model variants employ binary measures (use of patents, use of trade secrets, high effectiveness of patents, high effectiveness of secrets, effectiveness of patents dominate over trade secrets, or effectiveness of trade secrets dominate over patents) or the firms' assessment of the effectiveness of the two protection methods (measured on a four-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 effectiveness 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) that a firm i obtained in period z to the chosen protection method in period t :

$$in_out_{iz} = \alpha + \beta pm_{it} = \gamma X_{it} = \varepsilon_{iz} \quad (2)$$

where in_out covers quantitative measures of product innovation (sales with new products) and process innovation success (cost reduction). Control variables (vector X) include size, age, innovation input (level of innovation expenditure, type of innovation activity), and industry dummies. As innovation projects may stretch over more than one period, success of innovations protected in period t may occur only in a later period ($z > t$). Since we do not have information on the length on innovation projects, we cannot exactly determine the lag structure. In the empirical estimation, we measure innovation output both for the same period ($z = t$), which is usually done in the literature (see Hall et al. 2013), as well as with a one-year lag ($z = t + 1$).¹

In both models, endogeneity is an obvious challenge which may result from omitted variables or simultaneity of dependent and independent variables. In model (1), we try to limit endogeneity by including a large number of control variables so that the omitted variables bias is reduced as good as possible. In model (2), simultaneous causality may be a particularly important issue if the level of innovation success a firm aims to achieve would affect the choice of protection method. We believe, however, that this situation is of limited relevance in our setting. Achieving a certain level of innovation success is very hard to plan for a firm at the start of an innovation project (Hall and Sena 2011). On the one hand, it is uncertain whether the innovative idea can be realized. On the other hand, innovative actions of competitors (which affect the degree of novelty of a firm's new product) are difficult to observe. Firms will rather base their choice of protection method on the planned characteristics of their innovation in terms of level of novelty and how the innovation differs from existing offerings in the market. Nevertheless, we cannot exclude the possibility of endogeneity in our model estimations. Reducing or eliminating endogeneity by employing an instrumental variable approach turned out to be infeasible, given the large number of estimated models and the scarcity of potential instruments.

In line with many other empirical studies on the use and effectiveness of protection methods for innovation (see Hall et al. 2013; Hussinger 2006; Arora, Ceccagnoli, and Cohen 2008; Arora, Athreye, and Huang 2016; Arora, Cohen, and Walsh 2016; Czarnitzki and Toole 2011), all models are restricted to innovative firms. These are firms that have introduced a product or process innovation in the previous three

years. This restriction is straightforward, since non-innovative firms do not have innovations for which they would have to decide on a protection strategy, nor can innovation performance be observed for them.² The restriction implies, however, that all results and conclusions in the paper are limited to this group of firms, and no conclusion on non-innovative firms can be drawn from our study.

3.2. 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 an annual survey based on a panel sample. The survey is conducted by the Centre for European Economic Research located in Mannheim and is 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 trademark 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 trademarks as an alternative protection method.

For this paper, we use two recent survey waves that contain information on the use and effectiveness 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 effectiveness of eight methods used to protect a firm’s IP and innovations (see Figure A1 in the Appendix for the exact wording of the questions). The eight methods include patents, utility model patents, industrial designs, trademarks, copyrights, lead time advantages, complexity of goods or services, and secrecy. For each method, firms were required to state whether they had used it within the previous three-year period (2008–2010 and 2010–2012, respectively) and how important a role it played in their protection efforts. In 2010, effectiveness was rated in terms of the role methods played in protecting the firm’s IP; 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, effectiveness was measured on a three-point Likert scale (high, medium, low). We use this information to build six types of dependent variables for model (1): (1) categorical variables measuring the effectiveness of patenting and secrecy, respectively, as a method for protecting a firm’s innovations on a four-point Likert scale (no, low, medium, high effectiveness); (2) dummy variables indicating the use of patenting and secrecy, respectively; (3) dummy variables for patenting and secrecy, respectively, having a high effectiveness for protecting innovations; (4) dummy variables for using neither patenting nor secrecy, for using both, and for using only one of the two methods; (5) dummy variables for firms that either rate both patenting and secrecy of medium or high effectiveness or only one of the two; and (6) an indicator measuring the difference in effectiveness 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, for example the firm's most important innovation (see Arora, Cohen, and Walsh 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 what we do in this paper. Fortunately, the MIP collects information on the number of different innovation projects a firm has conducted within the three-year reference period, distinguishing between successfully completed, ongoing, and discontinued projects.³ This allows us to identify single innovation firms, that is, firms that have completed only one innovation project during the three-year period considered, and which have neither ongoing nor discontinued projects. Of all innovating firms in our sample, 24% are single innovation firms, and 39% of these single innovation firms combine patenting and secrecy. A caveat of this approach is that we do not know whether all firms apply the same concept of "innovation project." Some firms may consider innovation in an individual component of a product as an innovation project, whereas others may refer to the entire product. We try to ensure comparability of data by only considering firms as single innovators that reported a single completed innovation project and the introduction of a product innovation or process innovation during the same three-year period.

By focusing 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 substantially from the average innovator. Descriptive statistics (see Table A1) show that on average, single innovators are younger. There is, however, no significant difference in size, since many large firms are included in this group. The market environment in which single innovators operate seems to be quite similar to that of multiple innovators. Industry distribution of single innovators differs from that of multiple innovators, as single innovators are more frequently found in service industries. 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 in terms of both 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.

3.3. Variables

We use the following variables in the protection method decision model (1) to represent various determinants discussed in this section.

3.3.1. Strength of IP law

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.⁴ 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 at the three-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. As valid patents cover patent applications over the past 20 years and by a large share of firms that are not in our sample, we try to avoid the endogeneity problem that would arise when using sample responses on the use of patents to calculate the proportion of innovating firms using patents. 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.

3.3.2. Degree of innovation competition

We use a variable on a firm's assessment of the degree of technological uncertainty. High technological uncertainty will prevail if many firms compete for innovative solutions, and the outcome of a dominant technological solution is uncertain. 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 using a four-point Likert scale for the statement "The technological development is difficult to predict." 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) from those with few competitors (≤ 5). In addition, we add a dummy variable to indicate whether the number of competitors has recently increased.

3.3.3. Level of innovation

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 generated by the firm's innovative activities.

3.3.4. Type of innovation

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.

3.3.5. Open innovation practice

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 organizations, on the other.

3.3.6. Financial constraints

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), using lagged values as well.

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.

All models include size, firm age, 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 Tables A2 and A3.

4. 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 (see Table 1). In the 2012 survey, 74.1% of all innovating firms used trade secrets, while only 47.8% used patents.⁵ The higher share for trade secrets compared to patents largely reflects the fact that secrecy can be applied to virtually any innovation, while patent protection is limited to innovations that are based (at least partially) on inventions, that is, new

technological knowledge. 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%).

The difference is less marked when looking at firms that report that both patenting and secrecy is 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% (15.5% of single innovators) report this to be the case for patents.

The results for the 2010 survey differ from those for 2012 insofar as the proportion of innovating firms using secrecy or patenting is lower (57.3% for trade secrets, 36.8% for patents), while a larger share of firms rates 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 regard to secrecy is to be found in the different wording of the question. While the 2012 survey directly relates to the effectiveness of protecting innovations, the 2010 survey refers to a firm's IP in general. The results suggest that trade secrets are more effective in protecting a firm's general IP (which may also include IP, such as a customer list, not related to product or process innovation) than in protecting the competitiveness of innovations in the market.

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, Nelson, and John 2000; Cohen et al. 2002; Arundel 2001; Hanel 2008). When differentiating by size class, the findings become more diverse (see Table 2). Large firms still use trade secrets more frequently than patents, but they rate the effectiveness of patenting as higher than 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 1. Use of patents and trade secrets in innovating firms in Germany 2010 and 2012.

	Patents		Trade Secrets	
	2010a	2012 ^b	2010a	2012 ^b
<i>(1) Innovating firms with a single innovation</i>				
Use	38.4	45.0	60.6	62.5
Therein: high effectiveness	12.6	15.5	39.5	17.7
Therein: medium effectiveness	10.5	16.4	15.3	23.4
Therein: low effectiveness	15.4	13.2	5.7	21.3
Not used	61.6	55.0	39.4	37.5
<i>(2) All innovating firms</i>				
Use	36.8	47.8	57.3	74.1
Therein: high effectiveness	11.9	18.8	34.5	24.8
Therein: medium effectiveness	9.3	16.6	14.7	25.7
Therein: low effectiveness	15.6	12.5	8.2	23.6
Not used	63.2	52.2	42.7	25.9

Notes:

^aUsed for protecting the intellectual property of a firm.

^bUsed 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.

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 (see Table 3). Firms that use neither patenting nor secrecy either use other protection methods (e.g., trademarks, 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. Of these single innovators, 38.8% 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.

5. Estimation results

5.1. Protection method decision

We analyze a firm's choice regarding the use of secrecy and/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 secrecy and patenting use. This model variant investigates the determinants of a firm's choice to use both protection methods simultaneously, to rely only on one of the two, or to use neither patenting nor secrecy. Note that a firm's selection into one of the four groups is regarded as given and independent from the choice of using another combination. For comparison, Table A4 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 A5 presents the respective estimation results for firms that consider the effectiveness of trade secrets and patents to be 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 A6. Further model variants look at the relative effectiveness of secrecy over patenting by taking the difference between the secrecy and patenting ratings, as done in Hall et al. (2013; see Table A7), and by

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+
<i>(1) Innovating firms with a single innovation</i>						
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
<i>(2) All innovating firms</i>						
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.

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
<i>(1) Innovating firms with a single innovation</i>					
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
<i>(2) All innovating firms</i>					
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.

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 A8). Tables A9 and A10 show the results for the main model split by manufacturing and services. All models are estimated for single innovators and all innovators. The main results for single innovators (significance level of key variables) of the additional models (Tables A4–A10) are summarized in Table 5. 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).

The estimation results of the various model variants reveal a number of common findings. The strength of patent law is positively associated with the use of both patents and secrecy, but not with the use of only patents for single innovators.⁶ At the same time, firms operating in sectors with a high share of innovators with patents are less likely to rely only on secrecy. The results hold for both single innovators and for all innovators. When splitting the models by manufacturing and service sectors,⁷ the findings hold for both sectors, but they are stronger for service firms. 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. This result is mainly driven by manufacturing firms. The 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 5, second column). 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. When splitting by main sector, the result only holds

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 parentheses).

		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)	−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)	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 no. of competitors (D)	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)	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)	−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)	−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 Open innovation practice	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)
	Cooperation with businesses (D)	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)	−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)
Financial constraints	Credit rating (lagged)	0.051 (0.324)	0.002 (0.985)	−0.023 (0.656)	−0.031 (0.567)	0.040 (0.158)	−0.032 (0.438)	−0.007 (0.803)	−0.022 (0.402)
	High profit margin (lagged) (D)	−0.006 (0.951)	−0.133 (0.432)	−0.036 (0.710)	0.058 (0.557)	−0.039 (0.459)	−0.100 (0.201)	−0.013 (0.791)	0.041 (0.382)
	Low profit margin (lagged) (D)	−0.016 (0.902)	−0.014 (0.946)	−0.058 (0.643)	0.066 (0.592)	−0.078 (0.228)	0.087 (0.330)	0.025 (0.675)	−0.005 (0.931)
Controls ^a	Age (# years, log)	0.153*** (0.001)	0.008 (0.915)	−0.006 (0.894)	−0.136*** (0.002)	0.076*** (0.000)	0.042 (0.175)	−0.023 (0.228)	−0.062*** (0.001)
	Size (# employees, log)	−0.101*** (0.004)	0.023 (0.649)	−0.086** (0.012)	0.150*** (0.000)	−0.113*** (0.000)	0.019 (0.351)	−0.095*** (0.000)	0.151*** (0.000)
Applies to No. of observations		366 1246	57 1246	339 1246	484 1246	1543 5857	271 5857	1408 5857	2635 5857

Notes:

^aAll models include 15 sector dummies and an indicator for the survey wave used.* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

D, dummy variable.

for manufacturing, while service firms are more likely to rely only on secrecy when technological uncertainty is high.

Single innovators with new-to-market innovations favor 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 corresponds to that strand of literature that stresses that patenting is more commonly used for large innovations (Moser 2012). While we find a negative impact of both new-to-market innovations and innovation intensity on the use of only secrecy for all innovators, this effect becomes insignificant when looking at single innovators, suggesting that the negative effect is the result of employing different protection strategies for different innovations. The alternative variable specifications of combining secrecy and patenting support these results (see Table 5, third and fourth columns).

For single innovators with a process innovation, we find some confirmation of the view commonly expressed in the literature that process innovators opt for secrecy over patenting, though the statistical significance is rather poor. The estimation results for the relative effectiveness of the two protection strategies suggest that process innovators are less likely to use patents (Table 5, first and second columns), and they give secrecy a higher rating than patenting (see Table 5, fourth column). But when looking at which of the two strategies dominate, no significant impact is found (see Table 5, fifth column). There is also no significant effect on selecting into any of the four types of protection strategies investigated in Table 4 when considering all firms, while we find manufacturing firms with process innovation more likely to use neither secrecy nor patenting (see Table 5, sixth column). 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 (Table 5, first to third columns). The result that patenting is a less preferred protection method for process innovators compared to product innovators can reflect, on the one hand, higher costs of patenting compared to a low probability of knowledge spillover to competitors, since competitors can rarely access the process technology used by the innovator. On the other hand, many process innovations are based on the adoption of existing technology, for example by purchasing new equipment, which cannot be protected by a patent by the adopter. The inconclusive results on the use of secrecy may also be linked to the latter point: if firms introduce process innovation through the purchase of existing technology from equipment suppliers, there is no point protecting this technology, as it is available on the market.

Single innovators that collaborate with other businesses do not favor a certain protection strategy. The situation is very different for firms cooperating with universities and other research institutions. While they are more likely to combine secrecy and patenting, they do not rate one method as being more effective than the other. Our results suggest that firms tend to follow organizational openness in collaboration with business partners but try to prevent knowledge outflows when collaborating with academic researchers by both enforcing confidentiality agreements and patenting critical technological knowledge that has been developed as a result of the cooperation. One

Table 5. Determinants of secrecy and patenting: summary of model estimation results.

Reference table:	Relative Eff. S Over P										Manufacturing					Services				
	Use of S ^a					Use of P ^a					S & P Equd					Domf				
	Table A4	Table A5	Table A6	Table A7	Table A8	Table A9	Table A10	Table A11	Table A12	Table A13	Table A14	Table A15	Table A16	Table A17	Table A18	Table A19	Table A20	Table A21	Table A22	Table A23
Share of innovators with patents	+++	+	+++	+	+++	---	---	---	---	---	+++	---	---	---	---	---	---	---	---	---
Share of out-licensed patents	+++	+	+++	+	+++	---	---	---	---	---	+++	---	---	---	---	---	---	---	---	---
High technological uncertainty	+++	+	+++	+	+++	---	---	---	---	---	+++	---	---	---	---	---	---	---	---	---
Large no. of competitors	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Small number of competitors	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Competition has increased	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Market novelty	+++	+	+++	+	+++	---	---	---	---	---	+++	---	---	---	---	---	---	---	---	---
Innovation intensity	+++	+	+++	+	+++	---	---	---	---	---	+++	---	---	---	---	---	---	---	---	---
No innovation expenditure	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Process innovator	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cooperation with businesses	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cooperation with research	+++	+++	+++	+++	+++	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Credit rating (lagged)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
High profit margin (lagged)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Low profit margin (lagged)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Notes:

^aSecrecy or patenting of low, medium, or high effectiveness.^bSecrecy or patenting of high effectiveness.^cMeasured on a four-point Likert scale: not used, low, medium, high effectiveness.^dBoth patenting and secrecy are of medium or high effectiveness.^eSecrecy is of higher effectiveness than patenting, and patenting is of neither high nor medium effectiveness.^fPatenting is of higher effectiveness than secrecy, and secrecy is of neither high nor medium effectiveness.^g+++ , ++ , + (--- , -- , -) estimated coefficient positively (negatively) significant at the 1% , 5% , 10% level; S , secrecy; P , patenting; a , including firms using neither secrecy nor patenting; b , excluding firms using neither secrecy nor patenting; SOP0 , neither secrecy nor patenting is used; SOP1 , only patenting is used; SIP0 , only secrecy is used; SIP1 , both patenting and secrecy are used.

explanation would be that firms expect lower economic returns from opening their knowledge to academia in terms of new innovative ideas or complementary innovations. At the same time, firms may fear that knowledge sharing with academia results in more uncontrolled knowledge outflow due to the culture of knowledge sharing in public science, whereas collaboration agreements with business partners may be a sufficient tool to control knowledge flows to other businesses. 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.

Concerning financial constraints, 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. When splitting by main sector, we find that service firms with better credit rating tend to use neither secrecy nor patenting. 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.

5.2. Innovation output

The results of the innovation output models (Table 6) 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 A11). This result is supported by Table A12, which shows a weakly significant negative effect of the relative effectiveness of secrecy over patenting for the immediate new product success but not a significant effect if innovative sales in the following year are evaluated. When splitting by main sector (Tables A13 and A14 in the Appendix), a higher sales share of new-to-market innovations when using both secrecy and patenting is more pronounced for manufacturing firms. For service firms, using only patenting yields a higher sales share only immediately while the effect turns negative when considering a one-year lag.

We do not find a significant impact of the chosen protection method on innovation success with product imitations for all firms, suggesting that this type of innovation is difficult to protect effectively by using these two methods. When splitting by sector, service firms report lower sales with product imitations when relying only on patenting, while manufacturing firms show higher product imitation success when using only secrecy or both protection methods. For cost savings from process innovation,

there is a slightly positive impact of single innovators that rely more on secrecy than on patenting, which is driven by service firms.

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 artifact 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 use neither 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 commercialize innovations successfully.

6. Conclusion

This paper investigated the determinants and outcomes of firms’ decisions to protect their innovations through trade secrets and patents. We looked particularly at the role played by a combined protection strategy, that is, 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 used unique information on the number of completed innovation projects gained from the German innovation survey. By focusing 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 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 1246 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 cooperate with universities or other research organizations 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 to other protection strategies. While single innovators with new-to-market innovations are also more likely only to 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.

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. A main difference relates to process innovators who are less likely to use 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, while patenting is more effective for new-to-market innovations.

One main shortcoming of this research is the lack of panel data analysis. While 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, 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 of 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.

Notes

1. Our two-stage model would suggest applying a seemingly unrelated regression (SUR) approach to link the two models. We did not follow this approach, however, because in the empirical specification, we have four equations in the first stage (choice of both secrecy and patenting, only secrecy, only patenting, neither) and three equations in the second stage (new-to-firm sales, product imitation sales, cost reduction based on OLS models), which complicates the use of a SUR framework.
2. There may be a selection bias if firms refrain from innovation because they feel they are lacking the resources or competencies to deal effectively with protecting potential innovations. In the absence of adequate data, we did not control for this selection bias, which is in line with the related empirical literature.
3. This question, as well as a series of other questions we use in this paper, go beyond the harmonized CIS questionnaire and are not included in the questionnaires of other countries that participate in the CIS data collection effort.
4. 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.

5. 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 two-digit sectors, eight size classes, two 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.
6. The latter finding has to be read with caution due to the low number of observations for single innovators using only patents. For all innovators, patent strength increases the propensity to rely only on patents as a protection strategy.
7. Results of model estimations split by manufacturing and services industries are reported in [Tables A10](#) and [A11](#).

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References

- Alexy, Oliver, Paola Criscuolo, and I. Salter Ammon. 2009. Does IP Strategy Have to Cripple Open Innovation? *MIT Sloan Management Review* 51: 71–77.
- Alexy, Oliver, Gerald George, and I. Salter Ammon. 2013. Cui Bono? The Selective Revealing of Knowledge and Its Implication for Innovative Activity. *Academy of Management Review* 38 (2): 270–291.
- Anton, James J., and Dennis A. Yao. 2004. Little Patents and Big Secrets: Managing Intellectual Property. *RAND Journal of Economics* 35 (1): 1–22.
- Arora, Ashish. 1997. Patents, Licensing and Market Structure in the Chemical Industry. *Research Policy* 26 (4–5): 391–403.
- Arora, Ashish, Marco Ceccagnoli, and Wesley M. Cohen. 2008. R&D and the Patent Premium. *International Journal of Industrial Organization* 26: 1153–1179.
- Arora, Ashish, Wesley Cohen, and John Walsh. 2016. The Acquisition and Commercialization of Invention in American Manufacturing: Incidence and Impact. *Research Policy* 45 (6): 1113–1128.
- Arora, Ashish, Suma Athreye, and Can Huang. 2016. The Paradox of Openness Revisited: Collaborative Innovation and Patenting by UK Innovators. *Research Policy* 45 (7): 1352–1361.
- Arundel, Anthony. 2001. The Relative Effectiveness of Patents and Secrecy for Appropriation. *Research Policy* 30 (4): 611–624.
- Arundel, Anthony, and Isabelle Kabla. 1998. What Percentage of Innovations Are Patented? Empirical Estimates for European Firms. *Research Policy* 27 (2): 127–141.
- Aschhoff, Birgit, Baier, Elisabeth Dirk Crass, Martin Hud, Paul Hünermund, Christian Köhler, Bettina Peters, Christian., et al. 2013. *Innovation in Germany - Results of the german CIS 2006 to 2010*. Maastricht, the Netherland: ZEW Documentation 13-01.
- Belleflamme, Paul, and Francis Bloch. 2014. *Dynamic Protection of Innovations Through Patents and Trade Secrets*. Louvain: Université Catholique de Louvain.
- Bhattacharya, Sudipto, and Sergei Guriev. 2006. Patents vs. Trade Secrets: Knowledge Licensing and Spillover. *Journal of the European Economic Association* 4 (6): 1112–1147.
- Biswas, Tapan, and Julian McHardy. 2012. *Secrecy Versus Patents: Process Innovations and the Role of Uncertainty*. Department of Economics Working Paper 1749-8368, University of Sheffield.
- Bos, Brenda, Thijs L. J. Broekhuizen, and Pedro de Faria. 2015. A Dynamic View on Secrecy Management. *Journal of Business Research* 68 (12): 2619–2627.

- Brouwer, Erik, and Alfred Kleinknecht. 1999. Innovative Output, and a Firm's Propensity to Patent: An Exploration of CIS Micro Data. *Research Policy* 28 (6): 615–624.
- Buss, Philipp, and Christian Peukert. 2015. R&D Outsourcing and Intellectual Property Infringement. *Research Policy* 44: 977–989.
- Cassiman, Bruno, and Reinhilde Veugelers. 2002. R&D Cooperation and Spillovers: Some Empirical Evidence from Belgium. *American Economic Review* 92: 1169–1184.
- Cohen, Wesley M., Akira Goto, Akiya Nagata, Richard R. Nelson, and John P. Walsh. 2002. R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States. *Research Policy* 31 (8–9): 1349–1367.
- Cohen, Wesley M., Richard R. Nelson, and P. Walsh John. 2000. *Protecting their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or not)*. Cambridge, MA: National Bureau of Economic Research Working Paper 7552.
- Cordes, Joseph J., Henry R. Hertzfeld, and Nicholas S. Vonortas. 1999. *A Survey of High Technology Firms. Report to the Office of Chief Counsel for Advocacy at the United States Small Business Administration*. Washington: The George Washington University.
- Cosh, Andy, Joanne J. Zhang, Anna Bullock, and Isobel Milner. 2011. *Open Innovation Choices - What is British Enterprise Doing?* London: UK-Innovation Research Centre.
- Cugno, Franco, and Elisabetta Ottoz. 2006. Trade Secret vs. Broad Patent: The Role of Licensing. *Review of Law and Economics* 2 (2): 209–221.
- Czarnitzki, Dirk, and Andrew A. Toole. 2011. Patent Protection, Market Uncertainty, and R&D Investment. *The Review of Economics and Statistics* 93 (1): 147–159.
- Dass, Nishant, Vikram Nanda, and C. Xiao Steven. 2015. *Intellectual Property Protection and Financial Markets: Patenting vs. Secrecy*. Atlanta: Georgia Institute of Technology.
- Denicolò, Vincenzo, and Luigi Franzoni. 2004. Patents, Secrets, and the First-Inventor Defense. *Journal of Economics and Management Strategy* 13: 517–538.
- Erkal, Nisvan. 2004. On the Interaction Between Patent and Trade Secret Policy. *Australian Economic Review* 37 (4): 427–435.
- Giarratana, Marco S., and Myriam Mariani. 2014. The Relationship Between Knowledge Sourcing and Fear of Imitation. *Strategic Management Journal* 35 (8): 1144–1163.
- Gill, David. 2008. Strategic Disclosure of Intermediate Research Results. *Journal of Economics & Management Strategy* 17 (3): 733–758.
- Graham, Stuart J.H. 2004. *Hiding in the Patent's Shadow: Firms' Uses of Secrecy to Capture Value from New Discoveries*. GaTech TI:GER Working Paper Series, Georgia Institute of Technology.
- Graham, Stuart J.H., and Deepak Hegde. 2014. *Do Inventors Value Secrecy in Patenting? Evidence from the American Inventor's Protection Act of 1999*. New York: New York University.
- Graham, Stuart J. H., Robert P. Merges, Pam Samuelson, and Ted Sichelman. 2009. High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey. *Berkeley Technology Law Journal* 24 (4): 1255–1327.
- Hagedoorn, John, and Ann-Kristin Ridder. 2012. *Open Innovation, Contracts, and Intellectual Property Rights: An Exploratory Empirical Study*. Maastricht: UNU-MERIT Working Paper Series 2012-025.
- Hall, Bronwyn H., and Dietmar Harhoff. 2012. Recent Research on the Economics of Patents. *Annual Review of Economics* 4 (1): 541–565.
- Hall, Bronwyn H., and Vania Sena. 2011. *Innovation, IP Choice, and Productivity: Evidence from UK Firms. Report to the UK Intellectual Property Office*. Berkeley and Aston: University of California and Aston University.
- Hall, Bronwyn H., Christian Helmers, Mark Rogers, and Vania Sena. 2013. The Importance (or Not) of Patents to UK Firms. *Oxford Economic Papers* 65 (3): 603–629.
- Hall, Bronwyn H., Christian Helmers, Mark Rogers, and Vania Sena. 2014. The Choice Between Formal and Informal Intellectual Property: A Review. *Journal of Economic Literature* 52 (2): 1–50.
- Hanel, Petr. 2008. The Use of Intellectual Property Rights and Innovation by Manufacturing Firms in Canada. *Economics of Innovation and New Technology* 17 (4): 285–309.

- Hegde, Deepak, David C. Mowery, and Stuart J. H. Graham. 2009. Pioneering Inventors or Thicket Builders: Which U.S. Firms Use Continuations in Patenting? *Management Science* 55 (7): 1214–1226.
- Henkel, Joachim, Simone Schöberl, and Oliver Alexy. 2014. The Emergence of Openness: How and Why Firms Adopt Selective Revealing in Open Innovation. *Research Policy* 43 (5): 879–890.
- Huang, Fang, John Rice, Peter Galvin, and Nigel Martin. 2014. Openness and Appropriation: Empirical Evidence From Australian Businesses. *IEEE Transactions on Engineering Management* 61 (3): 488–498.
- Hussinger, Katrin. 2006. Is Silence Golden? Patents Versus Secrecy at the Firm Level. *Economics of Innovation and New Technology* 15 (8): 735–752.
- Jensen, Paul H., and Elizabeth Webster. 2009. Knowledge Management: Does Capture Impede Creation? *Industrial and Corporate Change* 18(4): 701–727.
- Klingebiel, Ronald, and Christian Rammer. 2014. Resource Allocation Strategy for Innovation Portfolio Management. *Strategic Management Journal* 35 (2): 246–268.
- Kultti, Klaus, Tuomas Takalo, and Juuso Toikka. 2006. Simultaneous Model of Innovation, Secrecy, and Patent Policy. *American Economic Review* 96 (2): 82–86.
- Kultti, Klaus, Tuomas Takalo, and Juuso Toikka. 2007. Secrecy Versus Patenting. *The Rand Journal of Economics* 38 (1): 22–42.
- Kwon, Illoong. 2012a. Patent Thicket, Secrecy, and Licensing. *The Korean Economic Review* 28: 27–49.
- Kwon, Illoong. 2012b. Patent Races with Secrecy. *The Journal of Industrial Economics* 60 (3): 499–516.
- Laursen, Keld, and Ammon J. Salter. 2006. Open for Innovation: The Role of Openness in Explaining Innovation Performance among U.K. Manufacturing Firms. *Strategic Management Journal* 27 (2): 131–150.
- Laursen, Keld, and Ammon J. Salter. 2014. The Paradox of Openness: Appropriability, External Search and Collaboration. *Research Policy* 43 (5): 867–878.
- Leiponen, Aija, and Constance Helfat. 2010. Innovation Objectives, Knowledge Sources, and the Benefits of Breadth. *Strategic Management Journal* 31 (2): 224–236.
- Lemley, Mark A. 2012. The Myth of the Sole Inventor. *Michigan Law Review* 110 (5): 709–760.
- Lerner, Josh. 1995. Patenting in the Shadow of Competitors. *Journal of Law and Economics* 38 (2): 463–495.
- Levin, Richard C., Alvin K. Klevorick, Richard R. Nelson, Sidney G. Winter, Richard Gibrert, and Zvi Griliches. 1987. Appropriating the Returns from Industrial Research and Development. *Brookings Papers on Economic Activity* 3: 783–831.
- Mairesse, Jacques, and Pierre Mohnen. 2010. Using innovation surveys for econometric analysis. In *Handbook of the economics of innovation*, edited by Bronwyn H. Hall, and Nathan Rosenberg, 1129–1155. Amsterdam and New York: Elsevier.
- Mosel, Malte. 2011. *Big Patents, Small Secrets: How Firms Protect Inventions When R&D Outcome is Heterogeneous*. Munich: Bavarian Graduate Program in Economics Discussion Paper 105.
- Moser, Petra. 2012. Innovation Without Patents: Evidence from World's Fairs. *Journal of Law and Economics* 55 (1): 43–74.
- Ottoz, Elisabetta, and Franco Cugno. 2008. Patent-Secret Mix in Complex Product Firms. *American Law and Economics Review* 10 (1): 142–158.
- Ottoz, Elisabetta, and Franco Cugno. 2011. Choosing the Scope of Trade Secret Law When Secrets Complement Patents. *International Review of Law and Economics* 31 (4): 219–227.
- Pajak, Serge. 2010. *Do Innovative Firms Rely on Big Secrets? An Analysis of IP Protection Strategies with the CIS 4 Survey*. Paris: Department of Economics and Social Sciences, Telecom ParisTech.
- Panagopoulos, Andreas, and In-Uck Park. 2015. *Patenting vs. Secrecy for Startups and the Trade of Patents as Negotiating Assets*. Crete: University of Crete.
- Perng Pan, Susan, and Sughrue Mion. 2010. *Hybrid Use of Trade Secret and Patent Protection in Green Technology*. *Bloomberg Law Reports* 3 (4). New York: Bloomberg.
- Peters, Bettina, and Christian Rammer. 2013. Innovation panel surveys in Germany. In *Handbook of innovation indicators and measurement*, edited by Fred Gault, 135–177. Cheltenham and Northampton/MA: Edward Elgar.

- Piening, Erk P., and Torsten O. Salge. 2015. Understanding the Antecedents, Contingencies, and Performance Implications of Process Innovation: A Dynamic Capabilities Perspective. *Journal of Product Innovation Management* 32 (1): 80–97.
- Png, Ivan P.L. 2016. *Secrecy and Patents: Theory and Evidence from the Uniform Trade Secrets Act*. Singapore: National University of Singapore.
- Png, Ivan P. L. 2017. Law and Innovation: Evidence from State Trade Secrets Laws. *Review of Economics and Statistics* 99 (1): 167–179.
- Ponce, Carlos J. 2007. *More Secrecy ... More Knowledge Disclosure? On Disclosure Outside of Patents*. Departamento de Economía Working Paper 07-72, Universidad Carlos III de Madrid.
- Schneider, Cédric. 2008. Fences and Competition in Patent Races. *International Journal of Industrial Organization* 26 (6): 1348–1364.
- Zaby, Alexandra K. 2010. Losing the Lead: The Patenting Decision in the Light of the Disclosure Requirement. *Economics of Innovation and New Technology* 19 (2): 147–164.
- Zhang, Tianle. 2012. Patenting in the Shadow of Independent Discoveries by Rivals. *International Journal of Industrial Organization* 30 (1): 41–49.
- Zobel, Ann-Kristin, Benjamin Balsmeier, and Henry Chesbrough. 2016. Does patenting help or hinder open innovation? Evidence from new entrants in the solar industry. *Industrial and Corporate Change* 25 (2): 307–331.

Appendix

(a)

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		
	1	2	1	2	high	medium	low
Formal measures							
Applying for <u>patents</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Applying for <u>utility patents</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Registering of <u>industrial designs</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Registering of <u>trademarks</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Copyright</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Strategic measures							
<u>Secrecy</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Complex design</u> of goods or services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Lead time advantage</u> over competitors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(b)

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?

	Degree of Effectiveness			Not used
	High	Medium	Low	
<i>Please mark one X for each line!</i>				
<u>Patents</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Utility Patents</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Design</u> registration	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Trade marks</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Copyright</u>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Lead time advantage</u> over competitors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Complex design</u> of goods / services	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<u>Secrecy</u> (incl. include non-disclosure agreements)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure A1. Questions on protection methods in the 2010 and 2012 German Innovation Surveys. (a) 2010; (b) 2012.

Table A1. Descriptive statistics for single innovators, multiple innovators and all innovators.

	Single Innovators	Multiple Innovators	<i>p</i>	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 (€1000 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
Continuous R&D (%)	38.9	48.9	**	46.8
Capital intensity (€1000 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

***p* < 0.01; **p* < 0.05 level.**Table A2.** Descriptive statistics for the protection method decision models.

	Firms with a Single Innovation				All Innovators			
	<i>M</i>	<i>SD</i>	Min	Max	<i>M</i>	<i>SD</i>	Min	Max
<i>Dependent variables</i>								
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 effective (D)	0.28	0.45	0	1	0.32	0.47	0	1
Patenting highly effective (D)	0.18	0.38	0	1	0.21	0.41	0	1
Relative effectiveness of secrecy (index)	0.53	1.31	−3	3	0.49	1.32	−3	3
Both secrecy and patenting effective (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
<i>Independent variables</i>								
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

(continued)

Table A2. Continued.

	Firms with a Single Innovation				All Innovators			
	<i>M</i>	<i>SD</i>	Min	Max	<i>M</i>	<i>SD</i>	Min	Max
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 (# years, log)	2.87	0.96	−0.69	6.15	2.98	1.01	−0.69	6.23
Size (# employees, log)	3.33	1.37	0.92	12.86	3.91	1.71	0.00	12.86
No. of observations	1246				5857			

Note: D, dummy variable.

Table A3. Descriptive statistics for the innovation performance models (2).

	Firms with a Single Innovation				All Innovators			
	<i>M</i>	<i>SD</i>	Min	Max	<i>M</i>	<i>SD</i>	Min	Max
<i>Dependent variables</i>								
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
<i>Independent variables, secrecy/patenting</i>								
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 effectiveness of secrecy (index)	0.51	1.29	−3	3	0.49	1.32	−3	3
<i>Independent variables, others</i>								
Size (# employees, log)	2.86	0.97	−0.69	6.15	2.97	1.00	−0.69	6.23
Age (# years, log)	−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	1033				4662			

Table A4. Determinants of using secrecy and patenting for protecting a firm's innovation/IP: results of bivariate probit models (estimated coefficients, significance levels in parentheses).

		Firms with a Single Innovation		All Innovators	
		Use of Secrecy ^a	Use of Patenting ^a	Use of Secrecy ^a	Use of Patenting ^a
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)
	High technological uncertainty (D)	0.388*** (0.000)	0.218** (0.011)	0.138*** (0.001)	0.098** (0.013)
Degree of innovation competition	Large no. of competitors (D)	−0.167 (0.118)	−0.189* (0.083)	0.053 (0.297)	−0.042 (0.409)

(continued)

Table A4. Continued.

		Firms with a Single Innovation		All Innovators	
		Use of Secrecy ^a	Use of Patenting ^a	Use of Secrecy ^a	Use of Patenting ^a
Level of innovation	Small number of competitors (D)	-0.137 (0.148)	-0.011 (0.903)	0.024 (0.586)	0.051 (0.232)
	Competition has increased (D)	-0.062 (0.527)	-0.036 (0.708)	0.069 (0.126)	0.038 (0.387)
	Market novelty (D)	0.312*** (0.001)	0.498*** (0.000)	0.337*** (0.000)	0.450*** (0.000)
	Innovation intensity (log)	0.120*** (0.000)	0.113*** (0.000)	0.098*** (0.000)	0.087*** (0.000)
Type of innovation	No innovation expenditure (D)	-0.934*** (0.000)	-0.988*** (0.000)	-0.963*** (0.000)	-0.816*** (0.000)
	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)	0.034 (0.771)	0.112 (0.295)	0.091 (0.112)	0.011 (0.830)
	Cooperation with research (D)	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)	0.055 (0.586)	0.027 (0.779)	0.060 (0.213)	0.020 (0.664)
	Low profit margin (lagged)	0.032 (0.789)	0.062 (0.617)	0.023 (0.704)	0.025 (0.670)
Controls	Age (# years, log)	-0.143*** (0.001)	-0.125*** (0.005)	-0.090*** (0.000)	-0.047*** (0.014)
	Size (# employees, log)	0.075** (0.021)	0.156*** (0.000)	0.089*** (0.000)	0.166*** (0.000)
Applies to (no. of observations)		823	541	4043	2906
No. of observations (total)		1246	1246	5857	5857

Notes:

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

^aSecrecy or patenting of low, medium, or high effectiveness.* $p < 0.1$; ** $p < 0.05$; $p < 0.01$.

IP, intellectual property.

Table A5. Determinants of secrecy and patenting being highly effective for protecting a firm's innovation/IP: results of bivariate probit models (estimated coefficients, significance levels in parentheses).

		Firms with a Single Innovation		All Innovators	
		Secrecy Highly Effective	Patenting Highly Effective	Secrecy Highly Effective	Patenting Highly Effective
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)	0.130 (0.148)	0.168* (0.080)	0.048 (0.223)	0.057 (0.196)
	Large no. of competitors (D)	-0.368*** (0.002)	-0.266** (0.043)	-0.036 (0.475)	-0.181*** (0.003)
	Small number of competitors (D)	-0.048 (0.609)	-0.062 (0.547)	0.004 (0.923)	0.078* (0.092)
	Competition has increased (D)	-0.028 (0.779)	-0.043 (0.705)	0.084* (0.055)	0.038 (0.446)

(continued)

Table A5. Continued.

		Firms with a Single Innovation		All Innovators	
		Secrecy Highly Effective	Patenting Highly Effective	Secrecy Highly Effective	Patenting Highly Effective
Level of innovation	Market novelty (D)	0.193** (0.036)	0.330*** (0.001)	0.244*** (0.000)	0.308*** (0.000)
	Innovation intensity (log)	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)	0.129 (0.229)	0.258** (0.020)	0.027 (0.584)	-0.010 (0.855)
	Cooperation with research (D)	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)	0.453*** (0.000)	0.100 (0.373)	0.101** (0.030)	0.102* (0.051)
	Low profit margin (lagged)	0.043 (0.736)	0.155 (0.264)	0.019 (0.741)	0.132** (0.041)
	Age (# years, log)	-0.104** (0.025)	-0.038 (0.451)	-0.107*** (0.000)	-0.044** (0.041)
Controls	Size (# employees, log)	0.032 (0.362)	0.135*** (0.000)	0.062*** (0.000)	0.171*** (0.000)
Applies to (no. of observations)		347	220	1880	1232
No. of observations (total)		1246	1246	5857	5857

Notes:

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

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A6. 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 parentheses).

		Firms with a Single Innovation		All Innovators	
		Effectiveness of Secrecy ^a	Effectiveness of Patenting ^a	Effectiveness of Secrecy ^a	Effectiveness of Patenting ^a
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)
	High technological uncertainty (D)	0.252*** (0.000)	0.178** (0.020)	0.093*** (0.004)	0.076** (0.026)
Degree of innovation competition	Large no. of competitors (D)	-0.226*** (0.008)	-0.199** (0.043)	0.018 (0.653)	-0.073 (0.102)
	Small number of competitors (D)	-0.095 (0.227)	-0.024 (0.770)	0.009 (0.800)	0.072* (0.051)
	Competition has increased (D)	-0.054 (0.501)	-0.038 (0.668)	0.062* (0.084)	0.028 (0.457)
	Market novelty (D)	0.243*** (0.001)	0.409*** (0.000)	0.280*** (0.000)	0.373*** (0.000)
Level of innovation	Innovation intensity (log)	0.083*** (0.001)	0.108*** (0.000)	0.079*** (0.000)	0.094*** (0.000)
		-0.764***	-0.836***	-0.797***	-0.801***

(continued)

Table A6. Continued.

		Firms with a Single Innovation		All Innovators	
		Effectiveness of Secrecy ^a	Effectiveness of Patenting ^a	Effectiveness of Secrecy ^a	Effectiveness of Patenting ^a
Type of innovation	No innovation expenditure (D)	(0.000)	(0.000)	(0.000)	(0.000)
	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)	0.106 (0.251)	0.168* (0.063)	0.061 (0.142)	0.010 (0.809)
	Cooperation with research (D)	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)	0.218*** (0.009)	0.053 (0.547)	0.072* (0.057)	0.056 (0.164)
	Low profit margin (lagged)	0.040 (0.677)	0.082 (0.457)	0.024 (0.619)	0.075 (0.136)
Controls	Age (# years, log)	−0.122*** (0.001)	−0.101** (0.011)	−0.099*** (0.000)	−0.053*** (0.002)
	Size (# employees, log)	0.057** (0.040)	0.161*** (0.000)	0.074*** (0.000)	0.174*** (0.000)
No. of observations		1246	1246	5857	5857

Notes:

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

^aMeasured on a four-point Likert scale: not used, low, medium, high effectiveness.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A7. Determinants of the relative effectiveness of secrecy over patenting for protecting a firm's innovation/IP: results of ordered probit models (estimated coefficients, significance levels in parentheses).

		Firms with a Single Innovation		All Innovators	
		Including Firms Using Neither Secrecy Nor Patenting	Excluding Firms Using Neither Secrecy Nor Patenting	Including Firms Using Neither Secrecy Nor Patenting	Excluding Firms Using Neither 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)	0.069 (0.301)	−0.014 (0.853)	0.019 (0.528)	−0.006 (0.849)
	Large no. of competitors (D)	−0.056 (0.489)	−0.042 (0.659)	0.077** (0.043)	0.086* (0.057)
	Small number of competitors (D)	−0.092 (0.222)	−0.063 (0.465)	−0.048 (0.162)	−0.043 (0.255)
	Competition has increased (D)	−0.000 (0.997)	−0.012 (0.896)	0.022 (0.514)	0.024 (0.527)
Level of innovation	Market novelty (D)	−0.125* (0.099)	−0.247*** (0.002)	−0.061* (0.068)	−0.152*** (0.000)
	Innovation intensity (log)	−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)	−0.043 (0.639)	−0.067 (0.501)	0.051 (0.225)	0.031 (0.475)
		0.023	−0.039	−0.065	−0.115***

(continued)

Table A7. Continued.

		Firms with a Single Innovation		All Innovators	
		Including Firms Using Neither Secrecy Nor Patenting	Excluding Firms Using Neither Secrecy Nor Patenting	Including Firms Using Neither Secrecy Nor Patenting	Excluding Firms Using Neither Secrecy Nor Patenting
Financial constraints	Cooperation with research (D)	(0.788)	(0.678)	(0.109)	(0.007)
	Credit rating (index, lagged)	−0.044 (0.264)	−0.017 (0.664)	−0.019 (0.340)	−0.013 (0.587)
	High profit margin (lagged)	0.114 (0.129)	0.179** (0.038)	0.004 (0.910)	0.023 (0.559)
	Low profit margin (lagged)	−0.022 (0.817)	−0.010 (0.928)	−0.047 (0.313)	−0.062 (0.241)
Controls	Age (# years, log)	−0.039 (0.221)	0.019 (0.640)	−0.043*** (0.003)	−0.020 (0.240)
	Size (# employees, log)	−0.073*** (0.005)	−0.105*** (0.000)	−0.073*** (0.000)	−0.097*** (0.000)
No. of observations (total)		1246	880	5857	4314

Notes:

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

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A8. Determinants of the combined effectiveness of secrecy and patenting to protect a firm's innovations/IP: results of probit models (estimated coefficients, significance levels in parentheses).

		Firms with a Single Innovation			All Innovators		
		Both Secrecy and Patenting ^a	Secrecy Dominating ^b	Patenting Dominating ^c	Both Secrecy and Patenting ^a	Secrecy Dominating ^b	Patenting Dominating ^c
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)
	High technological uncertainty (D)	0.202** (0.033)	0.140* (0.093)	−0.046 (0.697)	0.078* (0.063)	0.034 (0.373)	−0.019 (0.707)
Degree of innovation competition	Large no. of competitors (D)	−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)	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)	−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)	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)	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)	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)	0.196* (0.063)	−0.067 (0.495)	0.079 (0.569)	0.363*** (0.000)	−0.154*** (0.002)	0.045 (0.489)
	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)
Financial constraints	High profit margin (lagged)	0.204* (0.056)	−0.054 (0.576)	−0.148 (0.292)	0.114** (0.021)	−0.057 (0.204)	−0.036 (0.562)
		0.099	−0.062	−0.001	0.024	−0.036	0.176**

(continued)

Table A8. Continued.

		Firms with a Single Innovation			All Innovators		
		Both Secrecy and Patenting ^a	Secrecy Dominating ^b	Patenting Dominating ^c	Both Secrecy and Patenting ^a	Secrecy Dominating ^b	Patenting Dominating ^c
Controls	Low profit margin (lagged)	(0.465)	(0.603)	(0.993)	(0.703)	(0.530)	(0.017)
	Age (# years, log)	−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 (# employees, log)	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	1649	1846	548
No. of observations (total)		1246	1246	1246	5857	5857	5857

Notes:

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

^aBoth patenting and secrecy are of medium or high effectiveness.

^bSecrecy is of higher effectiveness than patenting, and patenting is of neither high nor medium effectiveness.

^cPatenting is of higher effectiveness than secrecy, and secrecy is of neither high nor medium effectiveness.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A9. Determinants of using secrecy and/or patenting to protect a firm's innovations/IP: results of probit models for firms from manufacturing industries (estimated coefficients, significance levels in parentheses).

		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 innova- tors with patents	−0.593 (0.196)	0.630 (0.292)	−0.286 (0.485)	0.654 (0.102)	−0.769*** (0.000)	0.414 (0.110)	−0.663*** (0.000)	0.875*** (0.000)
	Share of out- licensed patents	0.002 (0.957)	−0.079 (0.366)	−0.009 (0.757)	0.021 (0.512)	0.002 (0.911)	−0.047 (0.208)	−0.004 (0.821)	0.020 (0.245)
Degree of innovation competition	High techno- logical uncer- tainty (D)	−0.226* (0.079)	−0.228 (0.191)	−0.138 (0.259)	0.328*** (0.005)	−0.151** (0.013)	−0.068 (0.366)	−0.056 (0.301)	0.152*** (0.003)
	Large no. of competitors (D)	0.254* (0.099)	0.028 (0.909)	−0.207 (0.185)	−0.055 (0.708)	−0.028 (0.703)	−0.180* (0.100)	0.016 (0.817)	0.048 (0.471)
	Small no. of competitors (D)	0.112 (0.404)	0.270 (0.132)	−0.349*** (0.004)	0.077 (0.522)	−0.046 (0.462)	−0.068 (0.373)	−0.126** (0.026)	0.122** (0.019)
	Competition has increased (D)	0.150 (0.294)	0.219 (0.248)	−0.027 (0.840)	−0.172 (0.186)	−0.006 (0.923)	0.012 (0.888)	−0.053 (0.371)	0.029 (0.608)
Level of innovation	Market nov- elty (D)	−0.566*** (0.000)	0.336** (0.045)	−0.113 (0.369)	0.379*** (0.001)	−0.549*** (0.000)	0.229*** (0.003)	−0.152*** (0.006)	0.390*** (0.000)
	Innovation intensity (log)	−0.152*** (0.001)	−0.007 (0.899)	−0.023 (0.589)	0.118*** (0.005)	−0.128*** (0.000)	−0.060** (0.039)	−0.035* (0.087)	0.119*** (0.000)
	No innovation expenditure (D)	1.003*** (0.001)	−0.516 (0.295)	0.116 (0.712)	−0.714** (0.020)	1.144*** (0.000)	0.100 (0.648)	−0.078 (0.588)	−0.861*** (0.000)
Type of innovation	Process innov- ator (D)	0.256** (0.027)	−0.215 (0.186)	0.026 (0.811)	−0.145 (0.176)	0.095* (0.094)	−0.163** (0.026)	−0.009 (0.853)	−0.006 (0.907)
Open innov- ation practice	Cooperation with busi- nesses (D)	−0.226 (0.205)	−0.146 (0.512)	0.157 (0.278)	0.096 (0.486)	−0.125 (0.143)	−0.006 (0.950)	0.126* (0.062)	−0.047 (0.445)
		−0.152	−0.362*	−0.180	0.354***	−0.343***	−0.231**	−0.280***	0.459***

(continued)

Table A9. Continued.

		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	Cooperation with research (D)	(0.320)	(0.083)	(0.180)	(0.005)	(0.000)	(0.013)	(0.000)	(0.000)
	Credit rat- ing (lagged)	−0.006 (0.928)	0.001 (0.990)	0.040 (0.577)	−0.048 (0.504)	−0.004 (0.923)	−0.019 (0.671)	0.041 (0.262)	−0.028 (0.401)
	High profit mar- gin (lagged) (D)	−0.140 (0.338)	−0.124 (0.526)	−0.089 (0.506)	0.229* (0.076)	−0.074 (0.294)	−0.113 (0.225)	−0.055 (0.383)	0.112* (0.056)
	Low profit mar- gin (lagged) (D)	0.135 (0.426)	0.071 (0.769)	−0.242 (0.167)	0.110 (0.494)	−0.120 (0.153)	0.069 (0.506)	0.018 (0.812)	0.036 (0.613)
	Controls ^a								
Applies to	Age (# years, log)	0.109* (0.056)	0.046 (0.554)	0.037 (0.519)	−0.152*** (0.009)	0.029 (0.295)	0.068* (0.057)	−0.014 (0.574)	−0.047* (0.053)
	Size (# employ- ees, log)	−0.087* (0.083)	0.008 (0.902)	−0.188*** (0.000)	0.214*** (0.000)	−0.170*** (0.000)	0.025 (0.300)	−0.158*** (0.000)	0.218*** (0.000)
No. of observations		191	43	175	322	804	208	749	1959
		731	698	731	715	3720	3689	3720	3720

Notes:

^aAll models include 12 sector dummies and an indicator for the survey wave used.* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.**Table A10.** Determinants of using secrecy and/or patenting to protect a firm's innovations/IP: results of probit models for firms from service industries (estimated coefficients, significance levels in parentheses).

		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 innova- tors with patents	−0.481 (0.250)	0.193 (0.736)	−1.162*** (0.005)	1.303*** (0.001)	−1.505*** (0.000)	0.366 (0.249)	−0.549*** (0.003)	1.621*** (0.000)
	Share of out- licensed patents	−0.009 (0.907)	−0.018 (0.803)	0.096 (0.181)	−0.067 (0.320)	−0.054 (0.112)	−0.064 (0.297)	0.043 (0.187)	0.033 (0.323)
Degree of innovation competition	High techno- logical uncer- tainty (D)	−0.543*** (0.000)	−0.252 (0.348)	0.291** (0.028)	0.209 (0.120)	−0.116* (0.073)	−0.110 (0.358)	0.058 (0.345)	0.057 (0.366)
	Large no. of competitors (D)	0.160 (0.333)	−0.371 (0.342)	0.235 (0.138)	−0.268 (0.108)	0.065 (0.417)	−0.305* (0.067)	0.053 (0.485)	−0.054 (0.499)
	Small no. of competitors (D)	0.106 (0.504)	−0.172 (0.524)	0.234 (0.134)	−0.285* (0.068)	0.037 (0.634)	−0.093 (0.476)	−0.027 (0.721)	−0.008 (0.912)
	Competition has increased (D)	−0.170 (0.270)	0.037 (0.902)	0.219 (0.129)	−0.043 (0.775)	−0.146** (0.043)	−0.080 (0.560)	0.132* (0.052)	0.011 (0.876)
Level of innovation	Market nov- elty (D)	−0.501*** (0.004)	0.559** (0.047)	−0.026 (0.868)	0.397*** (0.007)	−0.484*** (0.000)	0.226* (0.084)	0.050 (0.486)	0.312*** (0.000)
	Innovation intensity (log)	−0.170*** (0.001)	0.136* (0.083)	0.056 (0.210)	0.072 (0.129)	−0.054** (0.023)	−0.069* (0.076)	−0.019 (0.401)	0.067*** (0.004)
	No innovation expenditure (D)	1.864*** (0.000)	.	−0.797** (0.037)	−1.237*** (0.008)	0.814*** (0.000)	0.308 (0.314)	−0.143 (0.380)	−0.807*** (0.000)

(continued)

Table A10. Continued.

		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
Type of innovation	Process innovator (D)	-0.085 (0.515)	0.079 (0.739)	0.085 (0.498)	-0.091 (0.476)	-0.103 (0.119)	-0.111 (0.363)	0.101 (0.111)	-0.001 (0.983)
Open innovation practice	Cooperation with businesses (D)	0.331* (0.095)	0.286 (0.344)	-0.402** (0.028)	0.095 (0.586)	-0.114 (0.285)	-0.040 (0.810)	-0.020 (0.828)	0.118 (0.198)
	Cooperation with research (D)	-0.463** (0.016)	0.509* (0.069)	-0.110 (0.544)	0.292* (0.091)	-0.247** (0.016)	0.418*** (0.006)	-0.098 (0.294)	0.144 (0.113)
Financial constraints	Credit rating (lagged)	0.159** (0.042)	0.102 (0.556)	-0.130* (0.094)	-0.027 (0.752)	0.097** (0.025)	-0.058 (0.487)	-0.066 (0.114)	-0.014 (0.753)
	High profit margin (lagged) (D)	0.160 (0.334)	-0.213 (0.576)	-0.003 (0.984)	-0.158 (0.334)	0.016 (0.835)	-0.025 (0.864)	0.075 (0.314)	-0.101 (0.193)
	Low profit margin (lagged) (D)	-0.207 (0.302)	-0.252 (0.532)	0.061 (0.749)	0.121 (0.535)	0.017 (0.871)	0.129 (0.480)	0.004 (0.965)	-0.083 (0.428)
Controls ^a	Age (# years, log)	0.212*** (0.005)	-0.153 (0.426)	-0.069 (0.340)	-0.102 (0.192)	0.134*** (0.000)	-0.036 (0.574)	-0.040 (0.207)	-0.087*** (0.010)
	Size (# employees, log)	-0.129** (0.012)	0.161* (0.069)	0.026 (0.588)	0.071 (0.182)	-0.060*** (0.004)	0.033 (0.393)	-0.007 (0.744)	0.056*** (0.007)
Applies to		175	14	164	162	739	63	659	676
No. of observations		515	471	515	515	2137	2137	2137	2137

Notes:

^aAll models include three sector dummies and an indicator for the survey wave used.* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A11. The impact of secrecy and patenting effectiveness on innovation success: results of ordinary least squares (OLS) models (estimated coefficients, significance levels in parentheses).

	Firms with a Single Innovation						All Innovators					
	New-to-Market Innovations			Only New-to-Firm Innovations			New-to-Market Innovations			Only New-to-Firm Innovations		
	No Lag	1-Year Lag	1-Year Lag	No Lag	1-Year Lag	1-Year Lag	No Lag	1-Year Lag	1-Year Lag	No Lag	1-Year Lag	1-Year Lag
Secrecy, low effectiveness (D)	0.183 (0.507)	1.266** (0.013)	0.506 (0.143)	0.329 (0.564)	-0.004 (0.986)	0.562 (0.301)	0.268* (0.086)	0.392 (0.146)	0.229 (0.205)	0.864*** (0.003)	0.156 (0.319)	1.018*** (0.002)
Secrecy, medium effectiveness (D)	-0.096 (0.704)	-0.157 (0.706)	0.517* (0.095)	0.390 (0.451)	-0.124 (0.613)	0.122 (0.808)	0.276* (0.054)	-0.005 (0.985)	0.336** (0.034)	0.555** (0.033)	0.148 (0.295)	0.698** (0.016)
Secrecy, high effectiveness (D)	0.257 (0.362)	0.400 (0.319)	0.451 (0.153)	0.422 (0.418)	0.329 (0.193)	0.577 (0.265)	0.605*** (0.000)	0.141 (0.546)	0.352** (0.020)	0.697*** (0.006)	0.432*** (0.002)	0.937*** (0.001)
Patenting, low effectiveness (D)	0.734** (0.013)	0.565 (0.238)	-0.582* (0.092)	-0.983* (0.079)	-0.043 (0.867)	-0.731 (0.153)	0.557*** (0.000)	0.346 (0.163)	0.065 (0.694)	-0.230 (0.386)	0.074 (0.624)	-0.142 (0.644)
Patenting, medium effectiveness (D)	1.145*** (0.001)	0.734 (0.143)	0.275 (0.415)	0.423 (0.439)	-0.152 (0.576)	1.702*** (0.005)	0.899*** (0.000)	0.608** (0.019)	0.207 (0.195)	0.217 (0.397)	-0.253* (0.091)	0.183 (0.579)
Patenting, high effectiveness (D)	0.996*** (0.001)	1.153** (0.024)	-0.203 (0.545)	0.010 (0.985)	-0.576** (0.020)	-0.144 (0.801)	1.343*** (0.000)	1.119*** (0.000)	-0.010 (0.953)	0.076 (0.758)	0.084 (0.579)	0.379 (0.244)
Size (# employees, log)	0.119 (0.152)	0.151 (0.248)	0.348*** (0.002)	0.776*** (0.000)	0.471*** (0.000)	0.533*** (0.003)	0.441*** (0.000)	0.526*** (0.000)	0.750*** (0.000)	0.965*** (0.000)	0.693*** (0.000)	0.835*** (0.000)
Age (# years, log)	0.128 (0.184)	0.235 (0.180)	0.041 (0.750)	0.045 (0.835)	0.008 (0.937)	0.054 (0.778)	0.018 (0.735)	-0.118 (0.227)	0.084 (0.154)	0.254*** (0.006)	-0.094* (0.074)	-0.008 (0.939)
Innovation intensity (log)	0.242*** (0.001)	0.271** (0.016)	0.207** (0.022)	0.286* (0.061)	0.129* (0.061)	0.285** (0.046)	0.297*** (0.000)	0.272*** (0.000)	0.262 (0.000)	0.295*** (0.000)	0.202*** (0.000)	0.358*** (0.000)
No innovation expenditure (D)	-1.830*** (0.000)	-1.985*** (0.015)	-1.319* (0.058)	-3.685*** (0.000)	-0.727 (0.157)	-2.681*** (0.002)	-2.042*** (0.000)	-2.285*** (0.000)	-1.127*** (0.000)	-2.884*** (0.000)	-1.672*** (0.000)	-2.551*** (0.000)
Continuous R&D (D)	0.948*** (0.000)	1.562*** (0.000)	-0.389 (0.132)	1.244*** (0.010)	0.528*** (0.009)	0.244 (0.597)	1.093*** (0.000)	1.118*** (0.000)	0.466*** (0.000)	1.416*** (0.000)	0.252** (0.031)	0.739*** (0.004)
No. of observations	1033	363	1033	360	1033	257	4662	1676	4662	1648	4662	1229

Notes:

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

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table A12. The impact of the relative difference of secrecy over patenting effectiveness on innovation success: results of OLS models (estimated coefficients, significance levels in parentheses).

	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 effectiveness of secrecy over patenting (index)	-0.148* (0.056)	-0.196 (0.113)	0.080 (0.326)	0.007 (0.960)	0.125* (0.051)	-0.009 (0.954)	-0.103*** (0.009)	-0.168*** (0.010)	0.056 (0.164)	0.067 (0.286)	0.073*** (0.049)	0.091 (0.242)
Size (# employees, log)	0.151* (0.070)	0.178 (0.188)	0.362*** (0.001)	0.811*** (0.000)	0.454*** (0.000)	0.525*** (0.002)	0.517*** (0.000)	0.575*** (0.000)	0.766*** (0.000)	0.998*** (0.000)	0.708*** (0.000)	0.895*** (0.000)
Age (# years, log)	0.082 (0.399)	0.212 (0.241)	0.033 (0.796)	0.042 (0.847)	0.013 (0.887)	0.017 (0.928)	-0.026 (0.621)	-0.141 (0.150)	0.074 (0.206)	0.238*** (0.010)	-0.102* (0.054)	-0.037 (0.723)
Innovation intensity (log)	0.298*** (0.000)	0.308*** (0.005)	0.229*** (0.009)	0.308*** (0.044)	0.115* (0.081)	0.326** (0.022)	0.367*** (0.000)	0.316*** (0.000)	0.277*** (0.000)	0.325*** (0.000)	0.216*** (0.000)	0.417*** (0.000)
No innovation expenditure (D)	-2.279*** (0.000)	-2.328*** (0.003)	-1.443** (0.034)	-3.827*** (0.000)	-0.645 (0.199)	-2.840*** (0.001)	-2.600*** (0.000)	-2.655*** (0.000)	-1.262*** (0.000)	-3.158*** (0.000)	-1.776*** (0.000)	-3.007*** (0.000)
Continuous R&D (D)	1.138*** (0.000)	1.834*** (0.000)	-0.318 (0.206)	1.352*** (0.004)	0.505** (0.012)	0.632 (0.168)	1.380*** (0.000)	1.281*** (0.000)	0.528*** (0.000)	1.510*** (0.000)	0.311*** (0.007)	0.908*** (0.000)
No. of observations	1033	363	1033	360	1033	257	4662	1676	4662	1648	4662	1229

Notes:

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

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.



Table A14. Effects of using secrecy and patenting on innovation success: results of OLS models for firms from service industries (estimated coefficients, significance levels in parentheses).

	Firms with a Single Innovation						All Innovators					
	Sales Share of New-to-Market Innovations			Sales Share of Only New-to-Firm Innovations			Cost Reductions Owing to Process Innovations			Sales Share of New-to-Market 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 only (D)	0.327 (0.321)	0.811 (0.167)	-0.151 (0.700)	-0.601 (0.358)	0.569* (0.074)	0.670 (0.319)	0.803*** (0.000)	0.508* (0.099)	0.048 (0.825)	0.681* (0.076)	0.461** (0.013)	0.937*** (0.015)
Patenting only (D)	1.540** (0.079)	-1.765** (0.026)	-1.819** (0.015)	-3.452*** (0.000)	-0.390 (0.491)	-1.257* (0.054)	1.543*** (0.001)	1.376 (0.163)	0.481 (0.341)	-0.144 (0.878)	-0.474 (0.200)	-0.058 (0.931)
Both secrecy and patenting (D)	0.920** (0.010)	0.400 (0.467)	-0.579 (0.157)	-0.745 (0.246)	0.207 (0.466)	0.520 (0.204)	1.246*** (0.000)	0.647** (0.045)	0.032 (0.888)	0.183 (0.651)	0.272 (0.161)	0.704* (0.072)
Size (# employees, log)	-0.014 (0.901)	0.170 (0.432)	0.081 (0.609)	0.344 (0.200)	0.212* (0.087)	0.235 (0.252)	0.293*** (0.000)	0.488*** (0.000)	0.610*** (0.000)	0.784*** (0.000)	0.472*** (0.000)	0.648*** (0.000)
Age (# years, log)	0.085 (0.569)	-0.066 (0.817)	0.051 (0.795)	0.501 (0.158)	0.048 (0.729)	-0.130 (0.450)	-0.015 (0.847)	-0.183 (0.226)	0.006 (0.952)	0.345* (0.068)	-0.028 (0.745)	-0.155 (0.356)
Innovation intensity (log)	0.170* (0.095)	0.255 (0.141)	0.370*** (0.002)	0.599*** (0.006)	-0.007 (0.936)	0.162 (0.422)	0.291*** (0.000)	0.393*** (0.000)	0.384*** (0.000)	0.391*** (0.001)	0.047 (0.439)	0.289** (0.010)
No innovation expenditure (D)	-0.915 (0.234)	-1.163 (0.342)	-1.706 (0.101)	-6.597*** (0.000)	-0.427 (0.446)	-1.236 (0.336)	-1.536*** (0.000)	-2.434*** (0.000)	-1.967*** (0.000)	-3.197*** (0.000)	-0.629 (0.110)	-2.084*** (0.005)
Continuous R&D (D)	0.864*** (0.005)	1.143** (0.039)	-0.418 (0.246)	1.068 (0.127)	0.441 (0.127)	0.679 (0.243)	1.146*** (0.000)	1.143*** (0.001)	0.245 (0.242)	0.916** (0.015)	0.308* (0.099)	0.337 (0.387)
No. of observations	416	142	416	142	416	105	1640	553	1640	544	1640	436

Notes:

All models include 3 sector dummies and an indicator for the survey wave used.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.