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Working Paper

Innovative start-up patenting: A new approach towards identification and determinants

Jena Economic Research Papers, No. 2013-023

Provided in Cooperation with:

Max Planck Institute of Economics

Suggested Citation: Wolf, Tina (2013) : Innovative start-up patenting: A new approach towards identification and determinants, Jena Economic Research Papers, No. 2013-023, Friedrich Schiller University Jena and Max Planck Institute of Economics, Jena

This Version is available at:

<https://hdl.handle.net/10419/85039>

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JENA ECONOMIC RESEARCH PAPERS



2013 – 023

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by

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www.jenecon.de

ISSN 1864-7057

The JENA ECONOMIC RESEARCH PAPERS is a joint publication of the Friedrich Schiller University and the Max Planck Institute of Economics, Jena, Germany. For editorial correspondence please contact markus.pasche@uni-jena.de.

Impressum:

Friedrich Schiller University Jena
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D-07743 Jena
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Innovative start-up patenting: a new approach towards identification and determinants

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There already exists broad literature investigating small and innovative firms in many respects. However, there have been few attempts to assess this group of firms' propensity to patent or its patenting activities. This paper intends to fill that gap. By applying a new approach to account for young and innovative companies' patents, this paper avoids an undercounting of small firm patenting, which has been a feature of most of the earlier studies. A data set is used that comprises information on R&D, capital stock, state promotion etc for 534 Thuringian firms in their first three business years. The results of the zero-inflated negative binomial regression analysis suggest that patenting is an activity of science-oriented, cooperative young firms that are conducting R&D even before the firm has been launched.

Keywords: entrepreneurship, technological innovation, patenting, firm performance, research and development

JEL-Codes: L25, L26, Q55

Acknowledgements: The author wants to thank Prof. Beibst, Prof. Cantner, PD Dr Schmitt-Rodermund and Prof. Silbereisen for making available data from the Thuringian Founder Study financed by the Thuringian Ministry for Culture and the Hans-Böckler-Stiftung. Additionally, the author thanks the German Science Foundation (DFG) for funding her position within the RTG 1411 "The Economics of Innovative Change". For fruitful comments, suggestions and criticism, the author wants to thank the members of the doctoral program RTG 1411 "The Economics of Innovative Change" and Prof. Cantner in special.

1. Introduction

Patents have been and are still frequently used in innovation studies (Brouwer and Kleinknecht 1999). Network studies also comprehensively use and have used patents as an indicator for cooperative R&D activities (for example Breschi and Lissoni (2006) analysed inventor networks, Cantner and Graf (2006) analysed applicant networks). Scherer (1983) was the first to attempt to systematically investigate firms' propensity to patent. In his argumentation, patenting is important to firms since patents contribute to monopoly power and first mover advantages. In this way, patents are drivers of the Schumpeterian (1912) idea of creative destruction and innovative competition as drivers for economic development.

This paper is devoted to this old research question, to which no satisfactory answer has yet been found, and it also asks about young and innovative firms: *What are the determinants of innovative start-ups' propensity to patent?*

The interesting fact, which is to be analysed in this paper, is that not every firm has the same propensity to patent. This means that, given a certain amount of innovation intensity, different firms may differ with respect to patenting intensity (Griliches 1990, Brouwer and Kleinknecht 1999). The causes for differences in patenting intensity are manifold. Scherer (1983) analysed the relationship between 1974 R&D expenditures and invention patenting by 4,274 lines of business in 433 US industrial corporations and found that the propensity to patent strongly varies across sectors but also modestly across firm characteristics such as overseas sales, federal R&D support, diversification, scope of invention use and invention type.

A year later, Bound et al. (1984) asked the questions: who does R&D and who patents? In order to find an answer, they investigated information on sales, employment, book value, pre-tax income, market value, R&D expenditures and patents applied for in 1976 for 2,595 firms in the manufacturing sector. Of these firms, 1,492 reported that they conducted R&D in 1976. With respect to the first question, they found that the industry determines who conducts R&D. Turning to the second question, they found that some of the firms which do R&D also patent, and that there is a strong positive relationship between the two activities. Additionally, those small firms that do R&D tend to patent more per R&D dollar than larger firms.

However, Brouwer and Kleinknecht (1999) criticised these early attempts by Scherer (1983) or Bound et al. (1984) by saying that such comparisons have the weakness that they cannot distinguish between a less efficient use of R&D inputs and (real) differences in the propensity to patent. In their paper, they solve this problem by measuring the results of the innovation process such that they analyse whether firms with a given innovation output, measured as the propensity to file at least one patent, differ with respect to their patenting intensity.

Moreover, Kleinknecht (1987) compares the results of the official Dutch R&D survey with findings of his own innovation survey in the Dutch manufacturing industry and concludes that there is an undercounting of small business R&D which is often informal and on a smaller scale compared with large firms (see also Pavitt and Patel (1988) making the same observation). Additionally, Blind et al. (2006) find that larger firms are more often inclined towards patenting activity for strategic reasons. This undercounting implies that the propensity to patent will be systematically biased by firm size if it is analysed in the way Scherer and Bound et al. did (Brouwer and Kleinknecht 1999). Moreover, (at least applicant-) networks that are created on the basis of patent data are biased towards larger firms (Boschma and ter Wal 2009).

Besides the undercounting of small firm R&D, these findings additionally suggest that different laws may govern the groups of small firms and larger firms (Bound et al. (1984) already implicitly mention this point). Hall et al. (2012a) even argue that start-ups constitute their own group among the group of small firms. Although there is now a broad literature investigating small and innovative firms in many respects (for example Acs and Audretsch 1990), there have been fewer attempts to analyse the factors related to the propensity to patent of these firms, not to mention for the group of innovative start-ups.

This paper is trying to fill this gap in analysing the propensity to patent of young and innovative firms in the eastern German federal state Thuringia. A data set is used which comprises information on R&D, capital stock, state promotion etc for 534 firms in their first three business years. Besides having the benefit that firm-level data (derived from a questionnaire) is combined with patent data (from the German Patent Office), the analysis has two advantages. First, it takes care of the problem that simply relating R&D to patent data leads to a mixing of a more or less efficient use of R&D and the propensity to patent (Brouwer and Kleinknecht 1999). Second, former studies basically matched patent data and survey data by searching for company names on the applicant side of the patent dataset. However, founders of young firms may show a tendency to apply for patents in their own names in order to avoid the risk of losing the property right after the firm has failed. Thus, the approach which has been used in former studies may lead to an undercounting of small and young firm patenting, simply because the wrong identification approach has been applied. A descriptive view on the data at hand reveals that only roughly 5.5% of the small and young firms apply for patents in the name of the company, the rest applies on the name of the founder(s). According to this, one may argue that not taking founders as applicants into account leads to an underestimation of small and young firm patenting as in the study of Hall et al. (2012b). This paper is trying to avoid such undercounting by using a new approach towards the identification of firms' patents. Instead of only searching the patent data base for the names of the

firms, also the names of the founders have been searched such that the tendency in young and innovative firms to apply for patents in the founders name has been taken into account.

2. Determinants of start-ups' propensity to patent

There is already a great deal of literature dealing with the decision to patent or, in other words, with the propensity to patent of firms. Hall et al. (2012a) give a broad literature overview on the choice between formal and informal securing of intellectual property rights. They describe the decision to patent or not as a trade-off between the benefits from using informal intellectual property rights and the costs that arise from it compared to relying on informal methods such as secrecy. As regards costs, financial expenditure and the possibility of enforcing the property right have to be taken into account. The benefits of safeguarding property rights arise basically from the ability to exclude competitors from the use of a new technology and from the potential to receive royalty fees if the patent is licensed (Arundel 2001, Harter 1994). Additionally however, patenting has advantages such as signalling the quality of an invention, improving public image, increasing bargaining power and the possibility of signalling expertise to potential research collaborators (see Hall et al. 2012a).

However, one main finding of the well-known Yale and Carnegie-Mellon surveys is that patenting strategies vary greatly across firms of different size. Although large firms generally use the patent system at a lower cost per patent than smaller firms, Hall et al. (2012a) argue that those firms specialising in knowledge production and the proof of innovative concepts may be small and that patenting becomes important for them since their assets are based on knowledge. However, even among small firms, start-ups may be a group of their own and have strategies that are different from those of established small firms (Hall et al. 2012a).

Regarding the patenting behaviour of young and innovative enterprises, two time dimensions have to be taken into account. First, there is the pre-founding phase, where the founders may work on their business idea and already apply for a patent that is then commercialised by means of creating the business (Walter et al. 2010). Since the founder's behaviour may be path-dependent, patenting activities in advance of founding the business may influence patenting over the whole lifespan of the firm. Additionally, it may be the case that a firm based on an invention which is so important that it has been patented may be innovative enough to go on patenting during its business years.

Second, after the firm has started, its characteristics influence whether it applies for patents or not. Analysing the 2008 Berkley Patent Survey, Graham et al. (2010) as well as Graham and Sichelman (2010) find that there are important differences in the patenting behaviour regarding the industries the firms are working in. Also they

find that strategic motives play a large role in start-ups' decision to patent. Start-ups seem to value the reputation effect that comes with very high rates of patent ownership. However, Graham et al. (2010) also find that financial constraints are most frequently the highest barrier to patenting for young firms. Analysing 370 US start-ups in the semiconductor industry, Hsu and Ziedonis (2007) find that patents can act as a signal for start-ups' innovativeness such that patenting firms may progress through the venture capital rounds of financing institutions more successfully. Additionally, Cantner and Kösters (2009) find state promotion to have a positive influence on start-ups' propensity to patent. Of course, such variables as the R&D intensity, cooperation, competition and the characteristics of the innovation (which also important for non-start-ups) may also play a role (Hall et al. 2012a).

2.1 Pre-founding phase

Before starting-up the firm, the potential founder, known as a nascent entrepreneur, is actively engaged in creating a new venture of his own (Wagner 2004). Among other activities, nascent entrepreneurs think seriously about their business, look for facilities/equipment, initiate savings to invest, invest money in the firm, organise the start-up team, write a business plan, buy facilities/equipment, search for financial support and licence/patent (see Wagner 2004; Reynolds 1997; Reynolds and White 1997). Walter et al. (2010) analysed the patenting behaviour of scientists before and after creating a spin-off and find that scientists increasingly commercialise their inventions through firm formation. However, potential founders who are not working as scientists may also conduct research and apply for a patent before and after creating a start-up. Walter et al. (2010) argue that the nascent entrepreneur (and this also holds for the entrepreneur in the business years of the firm) faces a trade-off between the patenting or otherwise of his business idea. On the one hand, patenting safeguards the knowledge base of the new venture against early imitation but on the other hand it facilitates early imitation by disclosing exactly this knowledge base (Arundel 2001, Harter 1994). Walter et al. (2010) find for academic founders that academics are more likely to patent if the search for marketable applications of the invention is highly uncertain, the technological field is rapidly changing, the field of research is one with high patent protection and the spin-off has high entrepreneurial orientation in the sense that the founders of the firm are innovative, pro-active and take risks. Thus, there are some factors influencing the nascent entrepreneurs' propensity to patent. But to what extent does this early patenting and R&D activity influence innovative success and thus patenting after the business has been launched? Firms that are built upon an innovation (be it patented or not) may have a higher propensity to innovate successfully in the future and thus patent more during their business life. This goes back to Dosi et al.'s

(1997) stylised facts of industrial dynamics that hold that there is significant heterogeneity in firm characteristics, behaviour and performance and that such diversity appears to be persistent. This means that prolific innovators at time t have a higher probability of remaining prolific innovators in period $t+1$. Although Giovanni Dosi did not relate his work on stylised facts to entrepreneurial activities, they may hold also for this field of research. Crépon and Duguet (1997) indeed find that past success in the production of innovation increases R&D efficiency. However, this effect seems to be non-linear in the sense that a small but positive number of innovations in the past positively affects the production of innovations in the present but this effect vanishes if the number of innovations increases.

Taking into account the arguments made above, one may formulate Hypothesis 1 in the following way:

Hypothesis 1: Patenting behaviour is path-dependent in the sense that patenting in the preparation process for founding the firm increases the patenting intensity after the firm has been founded.

2.2 Business years

In its business years, a start-up may be characterised by certain factors that influence the propensity to patent.

a. State promotion

Cantner and Kösters (2009) find that R&D-subsidised start-ups show a 2.8 times higher patent output and argue that these estimates provide evidence for the additionality of R&D subsidies within the first three business years. They reason as follows: state promotion may have an influence on patenting propensity for two reasons. Innovative firms receiving such programmes may have more financial scope, which may make it easier to apply for a patent and those firms may be more innovative since they have to apply for this support in a process where referees evaluate the innovativeness of their business idea. Following these arguments, an overall positive influence of state promotion on the propensity to patent may be expected. Hypothesis 2 thus states:

Hypothesis 2: Start-ups receiving state promotion show a higher patenting intensity.

b. Venture Capital

Applying for a patent and managing the patent portfolio is expensive. For small high-tech firms, Cordes et al. (1999) find that the costs of applying for and enforcing a patent were the leading reason why firms do not generally use patents.

For start-ups, Graham et al. (2010) as well as Graham and Sichelman (2010) found that financial constraints are the most significant barrier to patenting.

Firms starting with more money may find it easier to patent their business idea whereas 'poorer' founders may abandon this device of securing their idea and use the remaining money for other purposes. Additionally venture capital is usually given to young and innovative firms with high growth potential (Gabler 2013). Thus, if a firm receives venture capital, it does not just have more money to work with. Receiving venture capital also signals that this firm is seen (at least by the investors) as highly innovative with excellent future prospects.

According to these arguments, Hypothesis 3 will be:

Hypothesis 3: Start-ups with a venture capital budget are more innovative, can more easily apply for patents and will therefore patent more.

c. Cooperation

With respect to cooperative R&D activities, Brouwer and Kleinknecht (1999) argue that patenting serves as a vehicle for the formalisation of technology exchange agreements. They expect firms engaged in R&D collaboration projects to have an above-average propensity to patent since patenting may make it easier to treat a firm's knowledge as a tradable asset when it comes to negotiations over the conditions of technological partnerships. Additionally, Cowan et al. (2006) showed that cooperation has a positive effect on innovativeness and thus on patenting.

Based on these arguments, Hypothesis 4 may be formulated as follows:

Hypothesis 4: Firms that cooperate patent more since they are more innovative.

d. Scientific orientation

In general, patenting is associated with the R&D activity within firms (Hall et al. 2012a). If a firm's R&D is basically devoted to the newest scientific insights, the results of these activities may be new enough to be patentable. Thus, for firms conducting science-oriented R&D, the propensity to patent and their patenting intensity may be higher. As a consequence one may formulate Hypothesis 5 as follows:

Hypothesis 5: Firms conducting science-oriented R&D are more active in patenting with regard to the number of patents applied for.

3. Database and variables

Most of the recent empirical analyses on the impact of firm and industry characteristics on the propensity to patent use data from the Community Innovation

Survey (CIS), which has the advantage that it contains information on product and process innovation and on different channels for appropriability methods. Additionally, it provides cross-country insights that have already shown that some empirical regularities exist with respect to firms' propensity to patent. However, the database may underrepresent young and innovative start-ups since firms have to have at least 10 employees to be considered for the questionnaire. The questionnaire used as the basis for the data analyzed in this research paper has been specifically addressed to young and innovative firms, asking questions about the time period between three years before and after the firm was founded. Looking at the number of employees the firms had in the third business year, it becomes obvious that 72.68% have fewer than 10 and would not have been considered for the CIS.

Additionally, it is a new and doubtless useful trend to combine the CIS data with patent databases (e.g. Hall et al. 2012, Heger and Zaby 2012). This is usually done by matching the names of firms in the CIS with the names of applicants. However, using these combinations of databases, it is often found that small firms are less likely to patent than bigger firms. This paper will not argue against this finding but proposes a new approach for identifying firms' patents which may fit better for small firms and especially for young and innovative ones. Usually, when a firm is bankrupt, intellectual property rights are part of the remaining assets of the insolvent corporation. For newly-founded firms, the hazard of failing may be high enough for it to make sense to apply for a patent in the founder's name rather than in the firm's name since the founder can maintain ownership of the intellectual property even after the firm has collapsed. Therefore, when identifying firms' patents, patents applied for by the founders also have to be taken into account. A short descriptive analysis of the data at hand supports this idea. Among 534 firms in the database, 64 (11.89%) had patents in the first five business years. However, only 5.46% of the patents the 64 patenting firms applied for have been filed under the name of the firm. The rest were applied for under the name of the founder(s).

3.1 Database

The data used in the analysis was provided by the Thuringian Founder Study (Thüringer Gründer Studie), an interdisciplinary research project on the success and failure of innovative start-ups in the eastern German federal state of Thuringia. This dataset draws from the German trade register (Handelsregister, Abteilung A/B) for commercial and private companies established in Thuringia between the years 1994 and 2006. It is further restricted to start-ups in innovative industries, comprising 'advanced technology' and 'technology-oriented services' according to ZEW classification (Grupp et al., 2000). Furthermore, in addition to economic information, it contains information on the socio-demographic profile and psychological characteristics of the founders.

The survey population consists of 4,215 founders who registered 2,971 new entries in the Handelsregister. From the survey population, a random sub-sample of 3,671 founders was drawn and contacted. Due to team-started ventures, this corresponds to 2,604 start-ups in innovative industries. From January to October 2008, 639 structured face-to-face interviews were conducted with either the solo entrepreneur or with the lead entrepreneur of team start-ups. This resulted in a response rate of about 25%. There is no response bias with regard to industry structure and gender of founders.

The structured interviews were carried out by the members of the research project who were also supported by trained student research assistants. On average, an interview took approximately one-and-a-half hours. Retrospective data were collected relating to events in the founder's life and history of the business, covering the venture creation process and the first three business years of the start-up. To overcome entrepreneurs' hindsight bias and memory decay (Davidsson, 2006), the survey used memory aid techniques drawn from the Life History Calendar method (Caspi et al., 1996). The focus on firms in a single region (the German federal state of Thuringia) further allows holding constant key labour market and environmental conditions. Another important advantage of the study design is the possibility of interviewing founders of companies that had failed at the time of data collection. Hence, the sample is not biased toward surviving or successful firms.

Due to the fact that some of these start-ups were not genuinely new but subsidiaries or diversifications of existing companies, 71 observations were removed. Furthermore, 18 observations had to be removed from the analysis due to incomplete data. This reduced the number of valid interviews to 534.

Patent information was drawn from the German Patent Office. For the 534 firms where a face-to-face interview with either the solo entrepreneur or with the lead entrepreneur of team start-ups was conducted, the patent data base was searched for inventors with the same name as each of the founders. If a match was found, the members of the research project contacted the founders personally to ask whether they really applied for these patents. Furthermore, patents were searched for that were applied for directly by the start-ups in the sample. This procedure captures potential patents for innovations developed by employees working for the start-ups. The sum of patent applications was calculated for the three years before the first business year as well as for the first three business years. Double counts resulting from co-patenting of the founders were eliminated. Out of 534 firms where information on patent activity could be found, 64 (11.98%) applied for patents during the first three business years. The number of patents ranges between one and 16 patents per firm within the first three business years. Is an example to stress the worthiness of the new approach by considering the following: The 64 firms who applied for patents applied for 663 patents in sum. Among these 633 patents, only

38, this makes 5.46% have been applied for in the name of the company, the rest goes to the name(s) of the founder(s). This means that by using the other approach – which is identifying the patents only by searching the company name in the patent data base – only 5.46% of the patents that are related to the firms would have been identified.

Summary statistics for the variables used can be found in table 1.

3.2 Dependent variable and method

The outcome variable of interest for the analysis conducted in this paper is *No.Patents*, which represents the number of patents applied for by a firm during its first three business years. Although the number of patents applied for has been researched for all of the firms, it does not mean that each firm has also conducted R&D and tried to find a patentable invention. Thus the two reasons for reporting a zero count with regards to the number of patents applied for may be that the firm was unsuccessful in its innovation strategy or that the firm has simply not tried to be innovative. If the firm didn't try to innovate, the outcome would always be zero. However if the firm tried to innovate, the outcome could be zero or positive. Thus, two processes are going on that can produce zeros: unlucky R&D or no R&D at all (Falk and Falk 2011).

Looking at the database with regard to R&D activities in the first three business years, one can see that 324 firms are active and 19.75% (64) of them also applied for patents. This means that among the observations with a zero count in the number of patents, 210 have it because they did not conduct R&D at all and 260 count the zero because of unlucky R&D. Of course one has to be aware that unlucky R&D can also mean that the firm did not have enough money to apply for a patent, didn't count property rights as the right way to protect its knowledge or is waiting to apply for a patent for strategic reasons.

The most commonly used regression model for count data, which is the Poisson regression model, cannot be applied for the data at hand for two reasons. Apart from the fact that the variable *No.Patents* contains excessive zeros, it is also not surprisingly the case that 59.57% applied for one or two patents, the rest applied for between three and 16 patents. Thus the observations are skewed to the left. Additionally, the variance of the outcome variable (1.48) is quite large as compared to the mean (0.35), which might be an additional indication of over-dispersion (Cameron and Trivedi 2009).

This leads to the conclusion that the Poisson regression model doesn't fit the data and it appears that the variance of *No.Patents* is increasing faster than the Poisson model allows. In order to correct for overdispersion in the variable, negative binomial models have to be used for the analysis (Hausman et al., 1984). Since, as described above, the excess zeros are generated by a process separate from that

generating the count values, zero inflated negative binomial regression models are used. The zero inflated negative binomial model is a combination of two distributions, where the zeros stemming from not conducting R&D are assigned to the probability p and the rest $(1-p)$ to a negative binomial distribution (Mwalili et al. 2007). From a formal point of view, the zero inflated negative binomial distribution is given by:

$$P(Y = y) \begin{cases} p + (1-p)\left(1 + \frac{\lambda}{\tau}\right)^{-\tau}, & y = 0 \\ (1-p) \frac{\Gamma(y + \tau)}{y! \Gamma(\tau)} \left(1 + \frac{\lambda}{\tau}\right)^{-\tau} \left(1 + \frac{\lambda}{\tau}\right)^{-y}, & y = 1, 2, \dots \end{cases}$$

where the Y 's represent the patent counts for a single firm; $\frac{1}{\tau}$ can be interpreted as an overdispersion parameter such that when it becomes close to zero, the zero inflated poisson model should be used; p represents the probability of excess zeros. The probability of excess zeros in the patent count is then estimated as a logistic regression with $\log(\pi) = Z_i \beta$.

The resulting coefficients can be interpreted as the expected change in the log of the number of patents applied for if the explanatory variable is increased by one unit (holding the other variables constant).

3.3 Inflation

As already described above, the excess zeros in the count outcome variable *No.Patents* can result from unsuccessful R&D or no R&D at all. Since R&D activities usually take some time until a patentable innovation can be obtained, the inflation has to be analysed using the variable *R&DpreFounding* which is a binary variable indicating whether there have already been R&D activities in the three years before the firm has been founded. This variable has been derived from the question: *With respect to your product or service: did you conduct R&D in the three years before you started your business?* Having a descriptive look at the data at hand, one finds that 42.1% of all firms (532) had already conducted R&D in the three years before the firm was founded. Of these, 21% (47) applied for patents in the first three years after the firm was founded.

3.4 Negative Binomial Regression

a. Pre-founding patenting

Hypothesis 1 states that the patenting behaviour of a firm during its business years is dependent on past behaviour. The variable *PatentsBefore* measures whether one of the founders applied for a patent in the three years before founding the firm. Looking at the data, one sees that about half of the firms that applied for patents in the three years before the firm was founded also applied for patents in the three years afterwards.

b. R&D promotion

The variable *R&DPromotion* was derived from the question: *Did your firm draw on promotion for research and development in the first three business years?* This variable is one if the firm received state support and zero if not. In order to make it easier to remember this detail for the founder being interviewed, a list of German and Thuringian R&D promotion programmes was provided. As argued above, promotion for R&D may positively influence the patent output in terms of the number of patents a firm applies for.

Descriptive statistics reveal that among 353 firms where there is an observation, only 35.7% (126) received R&D support. 27.0% (34) of them applied for a patent in the first three business years.

c. Venture capital

The binary variable *VC* measures whether the firm received venture capital at the beginning of the first business year and is derived from the question: *Was there private venture capital available to your firm at the beginning of the first business year?* This variable is one if the answer is yes and zero otherwise. Venture capital, also called risk capital, is a temporary financial interest in young, innovative and non-market listed companies that are characterised by an above average growth potential. Thus, a firm receiving venture capital is evaluated by external persons to be more innovative than other firms and by receiving the money, this firm may find it easier to patent.

In the database at hand, receiving venture capital is quite a rare event. Only 21 of 364 firms (there have been many omissions in the database) received venture capital, which is a share of 5.7%. Four of them (19.0%) applied for a patent within the first three business years.

c. Cooperation

The variable *cooperation* is a binary variable and indicates whether the firm had cooperation projects in R&D or not. It is derived from the question: *Within the first*

three business years, did you cooperate in R&D? The variable is one if the answer is yes and zero otherwise. As described above, cooperating firms are more innovative as compared to isolated (non-cooperative) firms and it is more probable that they need to secure their knowledge as tradable asset, so they apply more often for patents. 144 of 317 (45.4%) firms for which there is an observation on cooperative behaviour reported having cooperated in R&D in the first three business years.

d. Scientific orientation

The variable *MeaningRes* measures the meaning of scientific insights for the development of the firm's product or service. It is derived from the question: *Which meaning had scientific insights and specific competencies of research institutes for the development of your product/service before the first business year?* *MeaningRes* ranges from one to five with one meaning 'completely unimportant' and five meaning 'very important'. The more important scientific findings are to the development of the business idea, the more innovative it is expected to be.

3.5 Controls

a. Product vs. Process firm

Product controls whether the firm is more devoted to offering products rather than services. This variable is derived from the question: *From which kind of output did you make the biggest share of your revenue?* This variable becomes one if the firm made the most of its revenue from a product and zero if it made it from a service or from a product and service equally. Product innovations are easier to patent than service innovations. Therefore firms offering products may have a higher propensity to patent and the number of patents applied for may be higher (Hall et al. 2012a).

b. Scientific education of the founder(s)

Persons having a PhD already have experience in R&D and may also intrinsically be devoted to innovations and patenting such that those persons in the founding team may carry out more patenting activity than those with a university degree as their highest degree. The variable measuring the share of founders with a PhD in the founding team is *Sh.Founders.PhD*. It can be expected that a higher proportion of founders with PhDs signals a higher technological level in the firm. This may be combined with a higher degree of innovativeness and thus patenting activity.

c. Team size

The more founders in the team, the more likely it is that one of them will have an idea that is patentable. Thus, the number of founders (*No. Founders*) is used as control variable in the respective estimations.

d. Spin-off

It has been found for this database that spin-offs have a higher propensity to patent (Cantner and Göthner 2012). Thus, the variable *Spin-off* is a binary variable, measuring whether the firm is a spin-off of a firm, university or research institute or not.

e. Patent intensive sector

As described in section 3.1 of this paper, the sample has already been selected into the direction of innovative industries such as ‘advanced technology’ and ‘technology-oriented services’ according to the ZEW classification (Grupp et al., 2000). However, in the questionnaire the interviewed founders could assign their firm to one of the seven sector categories. Since biotechnology, pharmaceuticals and chemicals have been found in earlier studies to be quite patent intensive (e.g. Bound et al. 1984), the dummy variable *BioChem* has been created to control for these patent intensive sectors.

f. Jena

The city of Jena can be said to be the innovative centre of the small German federal state Thuringia and it has the only University in Thuringia with so called ‘Promotionsrecht’, which is the admission to grant doctoral degrees. Thus, it may be the case that this region drives the result found in the estimations even more than the patenting itself. The dummy variable *Jena* is therefore used in order to control for this.

Table 1 Summary statistics

Variable	Description	Obs	Mean	Std.		
				Dev.	Min	Max
<i>No.Patents</i>	Number of Patents a firm applied for in the first three business years.	534	0,4064	1,5931	0	16
<i>PatentsBefore</i>	Dummy variable, indicating whether the founders were already active in patenting before founding the firm (1) or not (0).	534	0,0880	0,2836	0	1
<i>statepromotion</i>	Dummy variable which indicates whether the firm received R&D promotion in the first three business years (1) or not (0).	534	0,2116	0,4088	0	1
<i>VentureCapital</i>	Dummy variable is 1 if the firm received venture capital at the beginning of its first three business years and 0 otherwise.	364	0,0577	0,2335	0	1
<i>Cooperation</i>	Dummy variable which indicates whether the firm cooperated in R&D in the first three business years (1) or not (0).	317	0,4543	0,4987	0	1
<i>ScienceOrientation</i>	Five digit variable, indicating the meaning of scientific indights and specific competencies of reserach institutes for the development of the firms' product or service.	447	2,5615	1,5932	1	5
<i>Products</i>	Dummy variable, indicating whether the firm is more devoted to products (1) or services (0).	387	0,3850	0,4872	0	1
<i>Sh.Founders.PhD</i>	Share of founders holding a PhD.	473	0,1024	0,2529	0	1
<i>No.Founders</i>	Total number of founders.	534	2,1479	1,1156	1	5
<i>Spinoff</i>	Dummy variable, indicating whether the firm is an academic spin-off (1) or not (0).	534	0,2228	0,4165	0	1
<i>BioChem</i>	Dummy variable indicating whether the founders allocate their firm to the sector of biotechnology, pharmaceuticals and chemicals (1, zero otherwise).	532	0,0320	0,1760	0	1
<i>Jena</i>	Dummy variable indicating whether the firm is located in Jena (1) or elsewhere in Thuringia (0).	534	0,1255	0,3316	0	1
<i>R&DpreFounding</i>	Dummy variable, indicating whether the founders already conducted R&D in the preparation process of their firm founding.	532	0,4211	0,4942	0	1

4. Results

This section presents and discusses the results of the empirical analysis. Before doing this, however, some remarks concerning the control variables have to be made. First, the variable *Product* which is measuring whether the firm is offering products rather than services becomes significant over all estimations where it is included. Here a positive correlation with the number of patents applied for in the

first three business years can be found. Thus, the former findings by Hall et al. (2012a) can be supported; products are easier to patent than services.

The second control variable *No.founders* representing the size of the founding team is in one of the estimations significant and positive. Thus, the results hint in the expected direction: the more founders a firm has, the higher the probability is that they come to patentable ideas.

The dummy variable *Jena* has been included since a bias towards this region could have been expected. However, the estimations show that Jena has a significant but negative relationship with the number of patents applied for in the first three business years. This result is quite unexpected. It would mean, compared to all other regions in Thuringia, firms in Jena on average patent less. Since the number of patents a firm applies for is extremely skewed to the left and only 4% of the firms apply for more than five patents, the probability that these firms come from Jena is quite small, which may explain the unexpected finding.

The educational background of the founders (*Sh.Founders.PhD*), spin-offs (*Spinoff*) and the dummy for the most patent intensive sectors in the sample, namely biotechnology, pharmaceuticals and chemicals (*BioChem*), do not show any significant relation to the number of patents applied for in the first three business years.

4.1 Pre-founding phase

It has been argued earlier in this paper that patenting activities may be path dependent such that patenting carried out by the founders in the pre-founding phase may be positively related to patenting during the firms' business life. Table 2 shows the results.

For all estimations, patenting before founding the firm shows a positive and significant correlation with the number of patents applied for (patenting intensity). For all estimations, the observed coefficient ranges around 1.4. This indicates that the expected number of patents applied for by firms whose founders have already patented before starting it up is $\exp(1.4)=4.06$ times the expected number of patents applied for by firms whose founders do not have patenting experience. Hypothesis 1, stating that patenting is path dependent in the sense that if it is pursued during the process of preparing to found the firm, this increases the patenting intensity after the firm has been launched, can therefore not be rejected.

Table 2 Results of the zero-inflated negative binomial regressions

Method	Zero-inflated negative binomial regression			
	Model 1	Model 2	Model 3	Model 4
<i>Depvar</i>	No.Patents			
<i>PatentsBefore</i>	1.3212*** (3.03)	1.7124*** (2.93)	1.3011*** (3.03)	1.3291** (2.24)
<i>R&Dpromotion</i>	1.1281** (2.33)	0.7660* (1.90)	1.0791** (2.46)	0.9418* (1.77)
<i>VentureCapital</i>	0.1975 (0.34)	-0.5539 (-0.77)	0.2499 (0.47)	-0.1478 (-0.17)
<i>Cooperation</i>	0.8804** (2.41)	1.2656*** (3.28)	0.8704** (2.41)	0.5399 (1.24)
<i>ScienceOrientation</i>	0.2108* (1.65)	0.1417 (1.04)	0.2111* (1.66)	0.1074 (0.58)
<i>Products</i>	1.0822* (1.70)		1.0817* (1.71)	1.2691** (2.16)
<i>Sh.Founders.PhD</i>	-0.9912 (-1.62)		-0.9881 (-1.61)	-0.4543 (-0.39)
<i>No.Founders</i>	0.2230 (1.58)		0.2052* (1.69)	0.2095 (1.24)
<i>Spinoff</i>	-0.0882 (-0.24)			0.0907 (0.21)
<i>BioChem</i>	0.7940 (0.54)		0.2052 (0.58)	0.7344 (0.26)
<i>Jena</i>	-1.1630*** (-3.30)		-1.1476*** (-3.30)	
<i>Constant</i>	-2.6805*** (-4.29)	-2.0586*** (-3.03)	-2.6396*** (-4.41)	-2.5995*** (-3.83)
Inflate				
<i>R&DpreFounding</i>	-0.1999 (-0.28)	-1.0375 (-1.30)	-0.2072 (-0.29)	-0.2618 (-0.33)
<i>Constant</i>	0.2372 (0.35)	0.5633 (0.57)	0.2478 (0.37)	0.0609 (0.07)
No. of Obs.	114	185	114	114
Zero Obs	88	150	88	88
Prob>Chi	0.0000	0.0000	0.0000	0.0001
<i>/lnalpha</i>	-19.5512 (-0.03)	0.1444 (0.13)	-15.659 (-0.02)	-1.6621 (-1.07)
<i>alpha</i>	0.0000	1.1553	0.0000	0.1897
Robust z statistics in parentheses				
*significant at 10%, **significant at 5%, ***significant at 1%				

4.2 Business life

a. R&D promotion

R&DPromotion is a binary variable, indicating that a firm received public R&D support. In table 2 the coefficient for this variable becomes significant and positive for all estimations, indicating that there is a positive correlation between receiving this kind of state promotion and the patenting intensity of start-ups. More specifically, the expected number of patents applied for by firms which have received state promotion would be $\exp(0.96)=2.65$ times the expected number of patents applied for by firms without state promotion. Hypothesis 2 stating that start-ups that receive state promotion have higher patenting intensities cannot be rejected.

b. Venture Capital

Hypothesis 3 says that start-ups with a venture capital budget can more easily apply for patents and will therefore patent more. The respective variable *VentureCapital* does not show any significant relation to the dependent variable, namely the number of patents applied for, which leads to a rejection of hypothesis 3.

c. Cooperation

Looking at the results in table 2, cooperation in R&D has a significant positive correlation with effect on the number of patents applied for and this finding is stable over three of the four models. The expected number of patents applied for by cooperative firms is about $\exp(1)=2.72$ times the expected number of patents applied for by non-cooperative firms. This finding also fits to earlier studies on the positive effect of cooperation on innovativeness (Cowan et al. 2006). Cooperating firms are more frequently successful in creating innovations and thus apply more frequently for patents as compared to isolated (non-cooperative) firms. Thus, hypothesis 4 indicating that cooperation positively relates to patenting activities cannot be rejected.

d. Scientific orientation

The variable indicating a firms' scientific orientation is *ScienceOrientation*, which comprises the meaning of scientific insights for the development of the firm's product or service. Significant and positive results have been found in models 1 and 3 such that hypothesis 5, indicating that firms conducting R&D and basing their activities on scientific insights patent more, cannot be rejected. However, this effect seems to be related to the region of Jena since no significant result can be found if the dummy (*Jena*) is excluded.

4.3 Inflation parameter

Since the excess zeros in the outcome variable *No.Patents* can be the result of unsuccessful R&D or no R&D at all, R&D activities in the three years before the firm was started-up have been taken as inflation variable. However, the results in table 2 show that there is no significant correlation between research activities before the start-up is launched and the number of patents applied for in the first three business years.

5. Conclusions

In this paper, economic information as well as information about the socio-demographic and psychological profiles of the founders of 534 young firms operating in innovative industries has been analysed. The aim was to find out which factors are related to the propensity to patent in the form of the number of patents applied for by the group of young enterprises and in this way to assess the validity of patent data as measurement of innovative and cooperative activities. Contrasting with earlier studies e.g. by Hall et al. (2012b), this paper identifies a start-up's patents by taking applications made by the founders into account. Descriptive analyses have shown that only about 5.5% of start-up patents are applied for under the name of the firm. Thus, the undercounting of young and innovative firms' patenting activity in other studies e.g. in the above-mentioned may have been avoided here.

Regarding the whole database, it emerges that while 60.53% (322) of the firms report conducting R&D in the first three business years, 64 firms (19.88%) applied for patents. Arundel and Kabla (1998) find that 35.9% of product innovations are patented which would mean that the share of patenting firms among those conducting R&D should be around 36%. Since they analyse Europe's largest industrial firms and this paper's analysis looks at Thuringia's smallest firms (although the results are by no means comparable) it shows that on a comparative basis small firms seem to have a relatively high rate of patenting (20%) and that this can be detected more easily if the proposed procedure of identifying small firm's patents is applied, as in this paper.

It emerges that the main factors governing small firms' patent applications are 'patents before the firm founding', 'state promotion', scientific orientation' and 'cooperation'.

Regarding the pre-founding patenting behaviour, this paper's analysis detects a path dependency that goes in the direction of the success-breeds-success hypothesis formulated by Dosi et al. (1997). When founders have already conducted R&D and applied for patents in the nascent phase, they will also go on patenting after starting up the business. If patenting is considered a factor of success, policymakers should not ignore this relationship and include this indicator when considering funding for

young and innovative firms. Additionally, cooperation in R&D seems to support innovative success.

R&D promotion is also positively connected to patenting activities. As Cantner and Kösters (2009) argue, R&D support from the state may promote patenting activities for two reasons. Firstly, firms receiving such support have more financial scope and secondly, referees have evaluated the innovativeness of their business idea such that their patenting propensity may also be higher. When taking patents as an indicator of innovative success, the finding that state promotion positively influences patenting can be taken as a sign of successful state programmes.

Cooperation serves as a vehicle for the formalisation of technology exchange agreements (Brouwer and Kleinknecht 1999) and, following the arguments of the resource-based-view of the firm (Penrose 1959), they have a positive effect on firms' innovativeness (Cowan et al. 2006) such that cooperative firms may have a higher propensity to be active in patenting. The results for small and innovative start-ups in this paper indicate this. Policymakers thinking about programmes to enhance innovativeness in start-ups may therefore consider financial support for cooperative R&D projects.

The result that the scientific orientation or otherwise of the firms' R&D activities plays a role in patenting activity suggests that researchers should consider what kind of firms are in the sample if they analyse patent data. Taking all the findings together, one may argue that, when using patents as indicator for innovation or cooperation, one has to be aware of the fact that only the science-oriented ones, conducting R&D in advance and having R&D cooperation when the firm is founded are taken into account among all start-ups. However, although it has been argued that small firms may be a group of their own (Hall et al. 2012a) and that different laws may govern the groups of small firms and larger firms (Bound et al. 1984), the findings suggest that small firm patenting behaves in basically the same way as larger firm patenting. It is past success in patenting, cooperation and orientation towards the latest scientific insights that drives innovative start-up patenting.

Unfortunately, this study has some drawbacks that may be solved by future research. First, the firm database contains only Thuringian firms, which only represent a small part of Germany. Thus, it could be argued that future analyses should conduct a regionally broader analysis. However, a look at the maps created by Aamoucke and Fritsch (2013) shows that Thuringia is representative of most of Germany with respect to the average yearly number of start-ups in technology-oriented industries. This indicates the worthiness of the analysis, particularly for political decision-making.

Second, this analysis has been carried out under the assumption that all the firms have the same strategic reason for patenting, which is mainly the reputation effect (Hall et al. (2012a)). Unfortunately, such a question was missing in the

questionnaire provided by the Thuringian Founder Study. In future questionnaires, this kind of item should be included.

6. References

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Appendix

	<i>NoPatents</i>	<i>PatentsBefore</i>	<i>R&DPromotion</i>	<i>VentureCapital</i>	<i>Cooperation</i>	<i>ScienceOrientation</i>	<i>Products</i>	<i>Sh.Founders.PhD</i>	<i>No.Founders</i>	<i>Spinoff</i>	<i>BioChem</i>	<i>Jena</i>
<i>NoPatents</i>	1											
<i>PatentsBefore</i>	0,4938	1										
<i>R&DPromotion</i>	0,2068	0,2256	1									
<i>VentureCapital</i>	0,0021	-0,0031	-0,0700	1								
<i>Cooperation</i>	0,2083	0,1459	0,1790	0,0188	1							
<i>ScienceOrientation</i>	0,2247	0,2243	0,2640	0,0083	0,2730	1						
<i>Products</i>	0,1875	0,1631	0,2340	0,0738	0,0344	0,0514	1					
<i>Sh.Founders.PhD</i>	0,1961	0,1242	0,1720	0,0234	0,2229	0,2776	-0,0128	1				
<i>No.Founders</i>	0,1632	0,1588	0,1780	-0,0096	0,1352	0,1617	0,0392	0,0838	1			
<i>Spinoff</i>	0,1551	0,1278	0,1780	-0,0106	0,1243	0,1389	-0,0474	0,1700	0,2218	1		
<i>BioChem</i>	0,1041	0,1199	0,1290	0,1578	0,0622	0,1254	0,0761	0,2197	0,0359	0,0487	1	
<i>Jena</i>	0,1143	0,1102	0,1910	0,0491	0,0730	0,0982	0,0251	0,0794	0,1465	0,1017	0,0498	1
<i>R&DpreFounding</i>	0,1385	0,2200	0,3000	0,0619	0,0196	0,1975	0,1385	0,1022	0,1013	0,1710	0,1082	0,1378