The Impact of Family Ownership on Innovation: Evidence from the German Machine Tool Industry

Abstract

There has been much debate concerning the innovative output of family-owned and non-family-owned companies. The purpose of this study is to show that the impact of family ownership differs depending on important governance conditions. Drawing on secondary data from the German machine tool industry from 2000 to 2010, we show that it is not family ownership *per se* that drives or impedes innovation in terms of the number of patents granted to a firm. Increases in the degree of family ownership and the generation of the family reduce the innovative output, whereas dedicated family business institutions nurture it. We discuss the implications of our findings for research and management.

Keywords: innovation; family ownership; agency theory; patents; German machine tool industry

JEL: O32, L26

1. Introduction

Family ownership is pertinent in many national economies (Goel et al. 2012; Gomez-Mejia et al. 2011; Memili et al. 2015). However, the effect of family ownership on a firm's innovative output is still an issue of debate (e.g., Block 2012; Chrisman and Patel 2012; Duran et al. 2016). Family business research is more likely to consider management structures than the ownership dimension of family influence (Nordqvist et al. 2013). Studies on corporate governance focus on control over executives and the alignment of interests between owners and managers (Daily et al. 2003; De Massis et al. 2015), but they rarely examine the varying impacts of different owner identities on corporate outcomes (Judge 2012), especially innovation (Miozzo and Dewick 2002). Innovation research also lacks studies on the family ownership-innovation relationship (Crossan and Apaydin 2010; Ortega-Argilés et al. 2005). If the priorities and risk preferences of family owners influence, for example, acquisitions (Miller et al. 2010), diversification (Gomez-Mejia et al. 2010), or entrepreneurship (Nordqvist et al. 2013), they may also affect their companies' innovative output. Studies on the effect of family influence in terms of ownership and/or management on innovation report inconsistent findings (De Massis et al. 2013; Duran et al. 2016). These may be due to the widespread dichotomization of a company's status as either a family or a non-family firm (e.g., Memili et al. 2015; Munoz-Bullón and Sanchez-Bueno 2011), which hardly reflects the heterogeneity between and within ownership structures and owner groups (Chua et al. 2012). For instance, prior evidence suggests that the investment behavior of family-owned SMEs is more complex than that of large family firms. They are more likely to invest in innovation than their non-family-owned counterparts. However, their investments are less intensive and rather lead to incremental than radical innovation (Classen et al. 2014; Nieto et al. 2015).

Bridging the literatures on family businesses, innovation, and corporate governance, we make two contributions. First, we suggest that the family owners' impact on a company's innovative output depends on the extent of embeddedness of a company in an owner family (Le Breton-Miller and Miller 2009; Le Breton-Miller et al. 2011). Second, studies on innovation increasingly focus on young, science-based industries (e.g., Cardinal 2001; Furman and MacGarvie 2009; Sørensen and Stuart 2000). We put a traditional and stable sector, namely, the German machine tool industry at center stage, which faces strong pressures to remain innovative (Hirsch-Kreinsen 2000). It comprises mature, mainly small and medium-sized, family-owned companies – the "German Mittelstand" – that open the opportunity to observe innovation over generations (Duran et al. 2016; Giuliani et al. 2014; Goel et al. 2012). Moreover, within our study we follow a recent call in the family business field and incorporate the regional context of family-owned firms and its interrelatedness with (innovative) performance (Stough et al. 2015).

The article proceeds as follows. First, we present the theoretical framework. Second, we describe our data and the methods chosen for analyzing them. Finally, we report our findings and discuss their implications for research and management.

2. Theory and Hypotheses

Agency theorists suggest that, because of the concentrated ownership of family firms, information asymmetry is reduced, interests can easily be aligned, and investments help preserve the firm as a legacy for the family's descendants (Carney 2005; De Massis et al. 2015; Gomez-Mejia et al. 2011). Companies may suffer, if family owners use their power to appropriate value for their private purposes (Miller et al. 2013). They may prefer non-economic utilities to economically rational choices, if they are strongly embedded in family relationships and expected to be loyal to other family members even at the expense of their company's economic viability (Le Breton-Miller et al. 2011). We thus argue that the impact of family ownership on innovation varies based on the prevailing governance conditions (Carney 2005).

2.1 Degrees of Ownership

Innovation requires considerable efforts with uncertain outcomes (Miozzo and Dewick 2002). Owners must have good incentives to make potentially uncertain and irreversible investments in innovation. The more shares a family owns, the higher are its firm-specific investments in human and financial capital and the higher is its dependence on how well the company performs (Andres 2008; Carney 2005; Munari et al. 2010; Pedersen and Thomsen 2003). This dependence creates an emotionally charged structural embeddedness of the company in the owner family. The more that family owners are involved in decisions on innovation, the higher is their susceptibility to put more emphasis on the family agenda than on business issues (Le Breton-Miller et al. 2011). In the case of a high amount of shares in a family's hands, family owners' desire to pass on their firm and wealth to subsequent generations creates strong incentives to act cautiously and deter innovation (Gomez-Mejia et al. 2010). Thus, a high degree of family ownership negatively affects a company's innovative output (Chrisman and Patel 2012).

In companies with minority family ownership, the owner family's influence on innovation is limited. Minority equity stakes imply that only a limited amount of family capital is at risk. The embeddedness of the company in a family is hence rather low. This circumstance may promote family owners' investments in potentially risky innovation projects (Miller et al. 2010).

Hypothesis 1: The higher a firm's ownership by family members, the lower the innovative output of the firm will be.

2.2 The Generation of the Owner Family

Compared to founder-run (i.e., first-generation) firms, the number of decision-makers is higher in subsequent generations and decision-making is less centralized, because ownership becomes more dispersed (Sonfield and Lussier 2004). The increasing dispersion results from the increasing number of individual family members in each successive generation. The number of family members involved in the ownership system increases (Miller et al. 2013). The likelihood that factions emerge, that some family owners are dissatisfied with their role in the company or with strategic decisions, and that emotionally laden conflicts among factions or between generations arise is enhanced (Jaffe and Lane 2004; Miller et al. 2013). Due to these drawbacks, only a small fraction of family firms are passed to the second generation. An even smaller amount of these companies are passed to third-, fourth- or fifth-generation family ownership (Gilding 2003; Le Breton-Miller et al. 2004; Stavrou and Swiercz 1998).

The length of the relationship between a family and its firm influences innovation (Kang and Sørenson 1999). First, the longer the relationship between the family and the firm, the higher the likelihood of coordination problems is (Block 2012). Competing branches and camps are likely to form. The increasing number of family members in each successive generation fuels problems with succession, nepotism, or inter-personal conflicts, which spill over to the company and impede investments in innovation (Kellermanns et al. 2012; Schulze et al. 2001).

Second, higher-generation companies are more reluctant to risk the loss of family control over the owners' wealth than first- and second-generation family firms (Molly et al. 2012). The more dispersed family ownership is, the more family wealth is invested in the firm (Van den Berghe and Carchon 2003). This may lead to higher risk aversion and capital rationing because of the fear to lose the family's main source of intergenerational wealth (Pedersen and Thomsen 2003).

Third, the emotional attachment between the founder and the company is stronger than that between later-generation family owners and the firm (Kellermanns et al. 2012). Later-generation family owners may put more emphasis on their family identity than on their company, because they maintain contacts that are more frequent with their family members than with other stakeholders. The founding family's descendants may be more interested in the financial outcomes of their ownership stakes than the well-being of the company in the long run (Le Breton-Miller et al. 2011; Miller et al. 2013; Van den Berghe and Carchon 2003). Therefore:

Hypothesis 2: If family ownership goes beyond the second generation, the lower the innovative output of the firm will be.

2.3 The Institutionalization of Family Ownership

Family members who agree upon the direction of their business can effectively make decisions on investments in innovation, even if their shares are dispersed among many individuals or across branches or generations. If the family members' interests cannot be aligned, effective decision-making will be impeded (Le Breton-Miller and Miller 2009). Many families establish specialized governance mechanisms to mitigate the risks of intergenerational conflicts or misaligned interests (Berent-Braun and Uhlaner 2012; Schulze et al. 2001). They bundle their shares in, for example, family offices, trusts, family investment firms, or family holding companies. These family business institutions make decisions on behalf of all or a certain group of family shareholders (Gilding 2003; Jaffe and Lane 2004; Van den Berghe and Carchon 2003). Whether shares are held personally or by institutions is an issue of political embeddedness, which refers to the distribution of power among family members (Gilding 2003).

Family business institutions reduce the likelihood of family conflicts that may spill over into the firm and impede strategic decisions. They facilitate communication and inter-personal negotiation among family members with competing interests (Berent-Braun and Uhlaner 2012). By representing all or certain groups of family owners' collective interests, they enhance the objectivity of their decisions regarding the firm (Goel et al. 2012; Miller et al. 2013; Villalonga and Amit 2006). Family owners' susceptibility to family relationships is likely to decrease. This effect reduces the likelihood that the company serves private family benefits at the expense of its economic viability in the long run (Le Breton-Miller et al. 2011). Thus:

Hypothesis 3: The higher a firm's institutionalized ownership by a family, the higher the innovative output of the firm will be.

3. Methods

3.1 Sample and Data

The German machine tool industry is suitable to explore the suggested effects for several reasons. First, it is dominated by firms of the *Mittelstand*, i.e., traditional small and medium-sized family-owned manufacturing enterprises. It is an industry, which predominantly includes unlisted companies and in which family ownership takes a prominent role. Generally, high degrees of family ownership are preferred over other types of ownership (Fiss and Zajac 2004; Fohlin 2007; Lubinski 2011; Thomsen and Pedersen 2000).

Second, given the long tradition and maturity of the industry we can observe family-owned firms with a family tradition of several decades implying that they were passed on to the third or even later generations.

Third, despite its maturity the industry is highly innovative (Goel et al. 2012; Hirsch-Kreinsen 2000). The innovative output of the German machine tool industry in terms of patents per year is comparable to related industries, such as machinery and plant engineering, in both Germany and abroad (Vieweg 2001). Providing a strong protection of a company's proprietary knowledge, the link between patents and innovation is strong in those industries (Ahuja 2000; Gallié and Legros 2012).

For our analyses, we extended a dataset that had already been used by Coad and Guenther (2013). Our dataset starts from identifying the complete firm population of machine tool producers in Germany between 2000 and 2010 via the buyer's guide *"Wer baut Maschinen"* ("Who Makes Machines") and the *"Handbuch der Investitionsgüterindustrie"* ("Handbook of the Investment

Goods Industry") published annually by the VDMA (*Verband Deutscher Maschinen und Anlagenbau – German Engineering Federation*). In this period, 860 individual firms and their location were identified. From this original list, we excluded 42 companies as they were service or retail companies, which are not directly comparable to actual producers in their innovative activities. Based on this list, supplementary information was gathered using five additional databases.

First, for each firm, patent information – i.e., the number of patents granted assigned to the year of application – was retrieved from DEPATISnet, a database published by the German Patent and Trade Mark Office (*Deutsches Patent- und Markenamt*).

Second, data on ownership, the number of employees and turnover per year were provided by Dafne and Markus, two financial databases published by the Bureau van Dijk. Because most firms were not publicly traded, financial data could not be obtained for all companies and the entire time period, leading to a reduction of the number of observations usable in the statistical analysis. We used only those 341 companies in our analysis for which we could obtain information with respect to all variables. We consider a company as family-owned, if family members own at least twenty percent of the shares (Desender et al. 2013; Villalonga and Amit 2006).

Third, we scanned the company websites to gather information on the year of foundation and the generation of the owner family. For this purpose, we analyzed the chronicles or the "About us"-sections if available. Moreover, we used earlier versions of the buyers' guide *"Wer baut Maschinen"* to verify the foundation date. In order to rule out that the foundation date indicated in the Bureau van Dijk databases referred to the last change in legal status and did not reflect the actual founding year, we checked whether the company had already been active in the machine tool industry before the suggested date.

Fourth, to collect contextual data on the regional planning districts in which the companies were located, we used various issues of INKAR, a CD-based publication of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR; *Bundesinstitut für Bau-, Stadt- und Raumforschung*) within the Federal Office for Building and Regional Planning (BBR; *Bundesamt für Bauwesen und Raumforschung*).[1]

3.2 Variables and Measures

Innovative outputs are captured in various ways (Beaudry and Schiffauerova 2009; Crossan and Apaydin 2010). We measured *innovation* output for each firm by using the overall number of patents granted between 2000 and 2010 at their application date. This count variable represents the quantity of a company's innovative output and the legally granted rights to prevent other actors from using the novelty in question for their own purposes within a limited time span and a given country (Choi et al. 2011; Gallié and Legros 2012). Using patent count data as a measure of innovative output on the firm level has a long tradition in the field of economics, despite its potential flaws (Beaudry and Schiffauerova 2009). Latest since Griliches (1990), researchers have been aware (a) that not all innovations are patented, (b) of the general difficulty to categorize patents to a particular industry or even product class, and (c) of the hidden differences regarding the innovations', respectively the patents', economic impact and degree of novelty. However, Acs and Audretsch (1989) and Hagedoorn and Cloodt (2003) have shown that the overlap between the results of patent count data and alternative measures, such as company or total R&D, skilled labor (Acs and Audretsch 1989) or R&D inputs, patent citations, and new product announcements (Hagedoorn and Cloodth 2003) is strong, supporting the validity of patent count data as a measure of innovative output.

[1] Germany comprises 97 regional planning districts (*Raumordnungseinheiten*) that provide different conditions regarding spatial planning, urban development, educational standards, housing and building.

We measured *family ownership* with the percentage of shares owned collectively by the family (Block 2012; Munari et al. 2010). We used three dummy variables to differentiate between family-owned firms (above 20%), minor-family ownership (up to 20%), and no family ownership. The restrictive threshold of 20% corresponds to Villalonga and Amit's (2006) minimum control threshold. Previous studies relying on data from European countries (e.g., Faccio and Lang 2002) or on cross-country comparisons (e.g., La Porta et al. 1999) have also used this threshold. An ownership stake of twenty percent or more suggests a non-negligible impact on strategic decisions (Munari et al. 2010).

In contrast to Fiss and Zajac (2004), we did not use a proxy but scanned the chronicles published on the company websites to collect information on an owner family's *generation*. We distinguished between founder-run (i.e., first-generation), second-, third-, and fourth- or later-generation family firms (Villalonga and Amit 2006).

We further distinguished between personal and institutionalized family ownership. In contrast to Villalonga and Amit (2006), we separated the percentages of shares owned by individual family members (*personal*) from those held by dedicated family business institutions (*institutionalized*).

As control variables we included firm *age* (measured as the difference between the current year and the time that the firm was founded) and *size* (the average number of employees over the selected observation window) in our analyses (e.g., Arvanitis and Woerter 2009; Balasubramanian and Lee 2008; Huergo and Jaumandreu 2004; Sørenson and Stuart 2000). We included the past *stock* of a firm's patents and measured it with the natural logarithm of the number of patents prior to 2000, i.e., before the selected time period. This variable is a proxy for a firm's stock of knowledge. In case the patent stock was zero we added the value 1 before the transformation in order to avoid excluding these observations after the log transformation and at the same time keeping the information of a patent stock equal to zero (Chang et al. 2006). We expect that a firm that is experienced in patenting as reflected by its stock of patents before our observation window would be more likely to innovate than a firm to which a lower number of patents has been granted. To reflect the context in which the firms are embedded, we account for potential agglomeration externalities (Beaudry and Schiffauerova 2009) at the location of each company. These externalities affect innovation, because the selected industry "is characterized by highly tacit components and interactions of firms with external actors – such as customers, suppliers and universities – [which] are very important in the innovation process" (Giuliani et al. 2014, p. 683). We include the population *density* of the regional planning district (averaged over time) in which a company is located (Bottazzi et al. 2002; Furman and MacGarvie 2009) to control for Jacobs externalities, i.e., a potential increase in the innovative activities of firms based on an agglomerated area of diverse industries. We controlled for Marshall-Arrow-Romer (MAR) externalities by including the number of machine tool companies within the same regional planning district (Almeida et al. 2011; Robin and Schubert 2013; Vega-Jurado et al. 2009). Thereby, we measured the number of potential *cooperation* partners. For this measure, we referred back to the list of 818 firms from the buyer's guide including those for which we did not have full financial information but knew their location. For both measures, we used average values for the period 2000-2010. There is a long-lasting debate in the literature whether Jacobs or MAR externalities exists and under which circumstances they foster innovative performance of regions or individual companies (for an overview see Beaudry and Schiffauerova 2009). In comparable contexts of SMEs, MAR externalities enhancing innovation have been observed to be more important than Jacobs externalities (van der Panne 2004; Galliano et al. 2015). We therefore expected to see similar results in this study. We also considered the average number of universities and universities of applied sciences (*research*) in the region in which a company is located. These institutions provide valuable knowledge (e.g., via public-private partnerships) especially in the case of manufacturing companies

(Fritsch and Schwirten 1999; Giuliani et al. 2014; Miozzo and Dewick 2002) and human capital that may nurture innovation over time (Arvanitis and Woerter 2009; Robin and Schubert 2013; Simonen and McCann 2008). Finally, we included the number of years for which a firm was observed in the buyer's guide (*observed*). Table 1 provides an overview on the descriptive values for our variables.

Insert Table 1 about here

3.3 Analysis

Given that our dependent variable – the overall number of patents between 2000 and 2010 – is a non-negative count variable, we must apply regression models that can account for these characteristics of the data (Chang et al. 2006). Among the two standard approaches, the Poisson regression and the negative binomial model, only the latter approach, which is widely used in research drawing on firm-level patent data (e.g., Choi et al. 2011; Ortega-Argilés et al. 2005), allows to handle data showing overdispersion, i.e., the mean is smaller than the variance (in our study: mean = 10.011; variance = 1133.50).

As our dependent variable exhibits a high number of zeros (43.40 percent), meaning that many companies did not patent at all over the entire period, we applied the zero-inflated version of the negative binomial model. It splits the analysis in a two-stage procedure and assumes that two regimes exist that may lead to a zero outcome in the dependent variable. In one regime, the outcome variable is zero, i.e., a firm never patents. In the second regime, the outcome may be zero, but it can also be positive. In the first stage of the estimation, the probability of the regime one or two is estimated based on a set of independent variables via a logit analysis. In the second stage, a negative binomial is estimated for the second regime (Chang et al. 2006). In order to test whether the zero-inflated specification is preferred over the general negative binomial, we used the Vuong test

(1989). The test statistic indicates that the zero-inflated version is more appropriate, suggesting that our dependent variable has indeed an excess number of zeros.

4. Results

Table 2 reports the correlations between our study variables. In the analyses referring to both family- and non-family-owned companies, 341 cases are reported, among them 148 zero and 193 non-zero observations. Among all cases, we have 147 family-owned companies with 78 zero and 69 non-zero observations. On average, the sample firms are about 72 years old and have 1,564 employees. The average number of patents is higher for the full sample (n = 10.01; SE = 33.67) than for the family-owned companies (n = 7.89; SE = 37.41).

Insert Tables 2 and 3 about here

Table 3 reports the results of the zero-inflated negative binomial regressions. Model 1 includes the control variables. Model 2 shows that family ownership significantly decreases the number of patents. If family-owned shares are above twenty percent, fewer patents are granted to the firms. Firms exhibiting a minor family ownership of up to twenty percent, in contrast, do not differ in their innovative output from non-family-owned firms. Therefore, the results support Hypothesis 1. We gain further insights into the relationship of family ownership and the firms' innovative output by interpreting the results of the zero-inflated part, i.e., the estimates for the first-stage analysis. They reveal that family-owned firms are not systematically different from their non-family-owned counterparts. Family-owned firms do not systematically have zero patents more often.

In model 3a, we test the impact of the owner family's generation. The reference group in this model consists of non-family-owned companies or firms with minority family ownership (below twenty percent). The results illustrate that first-generation family firms do not significantly differ from the reference group. However, second- and later-generation family firms are significantly less innovative than their non-family- or minority-owned counterparts, supporting Hypothesis 2. This difference is especially obvious for third-generation family-owned firms ($p<0.01$).

These findings may reflect typical age effects on innovation (e.g., Balasubramanian and Lee 2008; Huergo and Jaumandreu 2004; Sørensen and Stuart 2000). In model 3b, we thus do not use the generation variables reported in model 3a but include the age of the company. The negative binomial part shows that firm age does not significantly decrease the innovative output. However, the negative and significant coefficient for this variable in the zero-inflated part clarifies that the older a company is, the less likely that firms do not have any patents at all.[2] Given that non-family-owned firms in our sample are on average older than family-owned firms (78.72 years vs. 61.36 years), we can rule out that family-owned firms are simply older and hence less innovative. In the same model, family ownership is negatively and significantly associated with the number of patents.

The interaction effect of family ownership and firm age in model 3c is negative and significant, though rather small. It indicates that the number of patents decreases, as family-owned firms get older. Non-family-owned firms or firms with only a minor family ownership do not suffer from a reduced innovative output as they mature. An explanation may be that family-owned firms are more path-dependent compared to non-family-owned companies because their leading, possibly non-family executives have a lower managerial discretion due to the family owners' involvement (Le Breton-Miller et al. 2011; Lubinski 2011).

[2] This result contradicts the general finding that older firms are less innovative. In our sample, it may be explained by the fact that the average age of the firms (71.24 years) and the age of the industry are high. Therefore, even higher firm ages do not reduce the innovativeness further. Moreover, age reflects a company's experience and skills, which it has developed throughout its history. These can be conducive to its absorptive capacity, which fosters innovation (Ortega-Argilés et al. 2005).

The models 4a and 4b that are used to test Hypothesis 3 are reported in Table 4. They allude to the subsample of family-owned companies only. Model 4a shows that institutionalized family ownership significantly increases the number of patents and, as reported in model 4b, personal family ownership reduces a firm's innovative output. These findings are in line with Hypothesis 3.

Insert Table 4 about here

Concerning the control variables, throughout all models our results reveal that a firm's stock of patents significantly drives innovation ($p<0.01$). The availability of potential cooperation partners in the same regional planning district positively affects a firm's number of patents. This result is in line with prior studies analyzing SMEs and their regional environment in the Dutch (van der Panne 2004) and French (Galliano et al. 2015) context, showing that MAR externalities exert a stronger influence on SME's innovative performance than impulses originating from a diverse surrounding (Jacobs externalities). However, this result is only significant, if the full sample is considered. In the models 4a and 4b that exclusively focus on family-owned companies, the coefficient for *cooperation* is positive but not significant. Against our expectations, the average number of universities in a region (*research*) does not drive the innovative output but tends to decrease it, although this effect is only marginally significant in some of our models.

5. Discussion and Implications

Overall, this study contributes to the literatures on innovation, family firms and corporate governance and creates a bridge between them.

First, it extends previous results by De Massis et al. (2015), which purely emphasize the degree of family involvement. The innovative output is not only affected by the degree of family ownership, but also by the owner family's generation, and whether or not ownership is institutionalized to a certain extent. The negative binomial part of the zero-inflated negative binomial regression models reveals that a higher degree of family ownership significantly decreases the innovative output. However, the zero-inflated part illustrates that family-owned companies are not systematically less innovative than their non-family-owned counterparts. Family ownership seems to impede the innovative output in companies as these become older. Non-family-owned firms do not suffer from this age effect in our sample.

Second, a decreasing amount of patents can be the outcome of an age effect that affects all companies over time, be they family- or non-family-owned (Balasubramanian and Lee 2008). While the generation indicates the age of the owner family, the number of years since foundation refers to the age of the company. Although these measures focus on different dimensions of the family business system, they are interconnected and linked via agency relationships (Fiss and Zajac 2004; Jaffe and Lane 2004; Van den Berghe and Carchon 2003). A decreasing amount of patents is not necessarily due to family ownership, because our analyses generally support the findings on the impact of age on innovation reported in prior research. However, the zero-inflated part illustrates that family-owned companies do not have systematically more often no patents compared to their non-family-owned counterparts.

Third, our study prompts to investigate the influence of the regional environment on innovative output in the context of family-owned businesses. The control variables reveal that the regional context exerts influence on how innovative a company is. As shown in Table 3, German machine tool companies benefit from potential cooperation partners in geographic proximity (*cooperation*, $p<0.05$), whereas a diversified environment does not significantly affect their innovative output (insignificant effect of *population density*). In this study, MAR-externalities nurture innovation. Jacobs externalities are not important in the selected context. So far, the analysis of a family firm's context or environment is mainly referred to as uncertainty associated with technological change

(Craig and Moores 2006) or competition within and across markets, countries, industries and individual sectors (e.g., Block 2012; Choi et al. 2012; Chrisman and Patel 2012; De Massis et al. 2013; Munari et al. 2010; Nieto et al. 2015). It largely remains on the country-level of analysis (Duran et al. 2016). Despite the intensive research in the area of agglomeration externalities (Beaudry and Schifferova 2009), the family business literature has not delivered unambiguous insights into the relation between the innovative performance of a family-owned business and regional influences (Pindado and Requejo 2015). Only Classen et al. (2014) introduce a broad regional dimension in their study of German family and non-family SMEs by differentiating between companies located in the Eastern or Western part of the country. So far, family business researchers at best examine the question how a region benefits from family firms in terms of, for example, regional economic growth and development (e.g., Memili et al. 2015). They have not yet studied how regional factors affect a family firm. The inclusion of indicators for agglomeration externalities can be seen as a first attempt to answer emerging questions referring to the extent to which regional contexts affect family firm behavior and how the effect of regional factors varies between family and non-family firms (Stough et al. 2015). Given that many family-owned SMEs are regionally embedded and appreciate sustainable relationships with regional suppliers, customers, and employees (e.g. Hammann et al. 2009), family-owned SMEs may benefit more from an innovative and closely connected neighborhood than their non-family-owned counterparts do. Analyzing these interplays and thereby combining regional science and family business research could add to our understanding of the drivers of family firms' innovative output and would complement the recent contributions regarding family businesses and their role in regional economic development (Stough et al. 2015).

Despite the questionability to generalize our findings to contexts other than the German machine tool industry, the major limitation that we see is the patent count measure. It is widely used in innovation research (Beaudry and Schiffauerova 2009), but it does not reflect whether an innovation is radical or incremental (Nieto et al. 2015) and whether universities in the same region are more likely to foster primarily practically applicable solutions than innovations that are patented. Future studies could test whether and under what conditions the innovative output is incremental or radical and how universities in close proximity to the observed companies affect the type of innovative output. Delivering insights regarding whether family- or non-family-owned SMEs tend to patent innovations of higher or lower economic impact by using patent citations analyses could further enhance our knowledge of the economic value of SMEs especially in the machinery sector.

As a managerial implication, our study calls attention to the antecedents of innovation. Family ownership does not systematically impede innovation in companies as these become older. It is rather a question of how families organize their ownership system. Family business institutions may decrease the potential for conflicts and facilitate decision-making across generations, because they reduce the embeddedness of the company in the owner family.

Table 1. Sample Description

	Mean	SD	Minimum	Maximum
Innovation: patents*	10.01	33.67	0	404
Size (average # employees)	1564.12	22355.49	1	412761.1
Age (years since foundation)	71.24	44.65	4	279
Patent stock	23.74	67.83	0	638
Population density (per qkm)	543.19	562.06	70.63	3816.91
Cooperation	18.69	19.98	0	62.1
Research	5.52	4.21	0	19.8
Observed	6.72	2.89	1	10
Family business (> 20%)**	0.43	0.50	0	1
Minority family ownership (10-20%)	0.06	0.24	0	1
Personal family ownership	0.39	0.47	0	1
Institutionalized family ownership	0.04	0.17	0	1

* Family-owned firms only (n = 147): 7.89 patents (SD = 37.41).
** Thresholds: 20-50% family ownership: 2 companies; 50-57%: 5 companies; >75%: 140 companies.
Generations: 1st generation: 57 companies; 2nd generation: 41 companies; 3rd generation: 26 companies; 4th or later generation: 23 companies.

Table 2. Correlations

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Firm size	1															
2	Patent stock	0.01	1														
3	Observed	-0.08	0.12**	1													
4	Cooperation	-0.02	0.14***	0.03	1												
5	Innovation (patents)	0.00	0.48***	0.10*	0.16***	1											
6	Population density	-0.05	0.07	0.01	0.31***	0.01	1										
7	Research	0.06	0.10*	-0.00	0.64***	0.09*	0.67***	1									
8	Family business	-0.05	-0.12**	-0.14***	-0.14**	-0.05	-0.11**	-0.19***	1								
9	Minority ownership	-0.02	-0.00	0.06	-0.03	-0.03	0.01	0.01	-0.22***	1							
10	1st generation	-0.03	-0.14***	-0.16***	-0.08	-0.11*	-0.06	-0.04	0.51***	-0.12**	1						
11	2nd generation	-0.02	0.00	-0.04	-0.02	0.09	-0.03	-0.09*	0.42***	-0.10*	-0.17***	1					
12	3rd generation	-0.02	-0.07	-0.04	-0.09*	-0.06	-0.09*	-0.08	0.33***	-0.07	-0.13**	-0.11*	1				
13	4th and higher generation	-0.02	0.03	0.04	-0.03	-0.00	0.02	-0.10*	0.31***	-0.07	-0.12**	-0.10*	-0.08	1			
14	Age	0.03	0.32***	0.31***	0.06	0.16***	0.03	0.00	-0.19***	0.12**	-0.44***	-0.09*	0.10*	0.29***	1		
15	Family personal	-0.05	-0.18***	-0.19***	-0.12**	-0.17***	-0.08	-0.16***	0.92***	-0.16**	0.50***	0.37***	0.35***	0.24***	-0.22***	0.94***	1
16	Family institutionalized	-0.01	0.14**	0.11**	-0.04	0.33***	-0.08	-0.09*	0.24***	-0.05	0.06	0.16***	-0.02	0.20***	0.04	0.24***	-0.12**

Notes:
N = 341. Significance levels: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 3. Results for Hypotheses 1 and 2

Parameter	Model 1	Model 2	Model 3a	Model 3b	Model 3c
Negative binomial part (number of patents as dependent variable)					
Constant	0.407 (0.293)	0.782** (0.314)	0.667** (0.296)	0.661** (0.324)	0.402 (0.367)
Firm size	0.000* (0.000)	0.000** (0.000)	0.000** (0.000)	0.000** (0.000)	0.000** (0.000)
Patent stock	0.465*** (0.077)	0.468*** (0.077)	0.481*** (0.075)	0.452*** (0.079)	0.474*** (0.074)
Observed	0.050 (0.038)	0.048 (0.039)	0.050 (0.038)	0.046 (0.040)	0.039 (0.038)
Population density	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Cooperation	0.020** (0.008)	0.018** (0.008)	0.019** (0.008)	0.019** (0.008)	0.018** (0.008)
Research	-0.072 (0.055)	-0.089 (0.054)	-0.092* (0.055)	-0.081 (0.054)	-0.082 (0.053)
Family ownership		-0.572** (0.258)		-0.490** (0.200)	0.106 (0.413)
Minority ownership		-0.495 (0.478)			
1st generation			-0.267 (0.358)		
2nd generation			-0.515* (0.291)		
3rd generation			-0.898*** (0.332)		
4th and later generation			-0.644** (0.269)		
Age				0.001 (0.002)	0.004 (0.003)
Family ownership X Age					-0.008* (0.004)
Zero-inflated part (likelihood of zero patents)					
Constant	-0.009 (0.667)	-0.558 (0.905)	-0.590 (0.890)	-0.120 (0.878)	-0.217 (0.925)
Family ownership		0.813 (0.710)	0.840 (0.664)	0.619 (0.618)	0.808 (0.633)
Minority ownership		0.432 (3.810)			
Firm size	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000*** (0.000)
Patent stock	-1.506** (0.663)	-1.511 (1.729)	-1.505** (0.750)	-1.473** (0.646)	-1.396** (0.629)
Observed	-0.068 (0.093)	-0.043 (0.130)	-0.040 (0.104)	0.037 (0.121)	0.034 (0.124)
Age				-0.014* (0.008)	-0.014* (0.008)
Fit statistics					
Overdispersion (α)	2.04	1.96	1.96	1.94	1.93
Log Pseudolikelihood	-819.44	-813.36	-813.34	-812.24	-810.86
Wald Chi^2	127.69***	132.97***	146.30***	133.66***	138.92***
Observations	341	341	341	341	341
Zero observations	148	148	148	148	148
Nonzero observations	193	193	193	193	193

Notes:
Significance levels: * p < 0.10; ** p < 0.05; *** p < 0.01. Robust standard errors in parentheses.

Table 4. Results for Hypothesis 3

Parameter	Model 4a	Model 4b
Negative binomial part (number of patents as dependent variable)		
Constant	0.151 (0.469)	1.132 (0.726)
Firm size	0.000*** (0.000)	0.000*** (0.000)
Patent stock	0.492*** (0.090)	0.491*** (0.090)
Observed	0.055 (0.064)	0.042 (0.063)
Population density	0.000 (0.000)	0.000 (0.000)
Cooperation	0.006 (0.011)	0.006 (0.011)
Research	-0.135* (0.074)	-0.137* (0.071)
1st generation	0.494 (0.356)	0.436 (0.341)
2nd generation	0.194 (0.282)	0.215 (0.279)
3rd generation	-0.030 (0.341)	0.060(0.348)
Institutionalized	0.788* (0.432)	
Personal		-0.996** (0.436)
Zero-inflated part (likelihood of zero patents)		
Constant	0.157 (1.832)	0.114 (1.724)
Firm size	-0.068* (0.038)	-0.070** (0.035)
Patent stock	-0.875** (0.416)	-0.872** (0.407)
Observed	0.280 (0.358)	0.280 (0.337)
Age	0.015 (0.010)	0.016 (0.010)
Fit statistics		
Overdispersion (α)	0.86	0.83
Log Likelihood	-258.71	-257.72
Wald Chi^2	270.55***	311.15***
Observations	147	147
Zero observations	78	78
Nonzero observations	69	69

Notes:
Significance levels: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Robust standard errors in parentheses. Fourth- and later-generation omitted for collinearity reasons.

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