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Family Ownership: Does it Matter for Funding and Success of Corporate Innovations?

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Abstract

Using the Mannheim innovation panel, we investigate whether family firms have higher financial need and how this affects both innovation input and innovation outcomes such as firm or market novelties, or process innovation. Applying the CDM framework, we find that family firms are more likely to have a latent financial need for innovation, which means that they have innovation ideas which they have not implemented yet. We find that family firms have a significantly lower marginal innovation productivity in particular for innovations with radical character, i.e., market novelties. We conclude from this evidence that family firms have a comparative disadvantage in innovation projects that imply high risk and require high innovation capability.

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1 Introduction

Corporate innovation is the driving force behind productivity and growth. Family firms play a crucial role since they are by far the most common firm type and are typically considered to be the backbone of the German economy. According to the Federal Association of German Industry, 90% of German firms are family owned businesses (*FB*). Most of them are small and medium sized companies (*SME*).[1] They account for more than half of all jobs in Germany (Gottschalk et al., 2014). Therefore, understanding how family ownership impacts the availability of funding and success of corporate innovations is crucial.

A firm's innovation capability affects corporate innovation and also the likelihood of financial constraints. For a given amount of internal funds, high innovation capabilities induce particularly large funding gaps if access to external funding is restricted (Hottenrott and Peters, 2012). Large funding gaps create high financial needs. In addition, financial access is particularly difficult for innovators as information asymmetries are large and innovative success is highly uncertain. Collateral can improve financial access (Bester, 1985). However, innovation is typically associated with intangible rather than tangible assets, which hardly qualify as collateral (Brown et al., 2012; Cosci et al., 2016; Hall et al., 2016).

Does family ownership alleviate or aggravate the funding gaps of innovative firms? With the exception of Hottenrott and Peters (2012), the question concerning the association between financial constraints and innovation is widely neglected in previous research.[2] We study the differences between family and non-family firms in the relationship between innovation capabilities, funding gaps and innovation performance. In contrast, Hottenrott and Peters (2012) discuss briefly how family ownership affects financial constraints, but neglect whether specific funding gaps of family firms have an impact on innovation expenditure

[1] According to Gottschalk et al. (2014) over 99 percent of *FB* have less than 250 employees.
[2] See also the overview of Nanda and Kerr (2015).

and output.

Innovation success requires transforming R&D investment into innovation output, and finally into productivity and turnover (Classen et al., 2014). Previous research taking this multistage process into account does not capture the potential interdependence between family ownership and funding gaps. Classen et al. (2014) were the first to compare innovation in family firms versus non-family firms (*NFB*) by employing two distinct categories of innovative success: process and product innovation. However, they ignore potentially disproportionate gaps in funding innovations between *FB*s and *NFB*s.

These research gaps are surprising. On the one hand, specific funding gaps of family firms may affect directly R&D expenditure and indirectly the firm's effectiveness in generating innovation output. On the other hand, typical characteristics of family firms, such as alignment of owner-managers' interests (Berle and Means, 1991) and long-term orientation (Zellweger and Sieger, 2012), have the potential to increase effectiveness in the transformation process and to compensate – at least partly – for possibly disproportionately high funding gaps. In addition, funding gaps and its interaction with family ownership may generate different results depending on whether process innovation or product innovation is considered. Overall, the question of how funding gaps interact with family ownership across interdependent stages of the innovation process and across different types of innovation output is still open.

We study these issues with data from the Mannheim innovation survey. The German data are particularly suitable for our purpose. Family ownership is the prevailing governance structure in Germany and its global competitiveness is highly dependent on the innovative strength of its firms (Cornell University et al., 2016). Specifically, we apply the CDM approach in our study (Crépon et al., 1998; Classen et al., 2014). The recursive system of equations accounts for potential interdependencies between different stages of innovation. The first equation describes how a firm's financial need is related to its innovation capability and firm type. This equation allows us to identify whether the financial need of a particular firm has its origin in disproportionately high innovation capabilities or unfavorable funding conditions. The second equation models how innovation input is affected by financial need, firm type and their interaction. The third equation captures the potential interaction between innovation input, firm type and financial need in determining the innovation output. The system is completed by labor productivity as a function of innovation output, firm type and financial need.

The results reveal that family ownership matters. Family firms have, on average, significantly higher financial need for innovation, even after controlling for structural differences such as size, industry, innovation capability and access to different funding sources. This means that *FB*s are more likely to have latent innovation projects that are not conducted either because of insufficient financial resources or because *FB*s assess the economic risk of innovation as being too high.

Overall, we find that compared to *NFB*s, *FB*s have very similar levels of innovation inputs and outputs. However, they have lower marginal innovation productivity, meaning that increasing innovation expenditure yields less innovation outcome in terms of market novelties for *FB*s compared to *NFB*s. When compared to *NFB*s, *FB*s have a higher risk aversion and a lower innovation capability, and might not be able or willing to conduct radical innovation projects.

This paper makes three contributions to the literature. First, we link innovation capabilities to the specific financial needs of family firms. Second, we amalgamate the financial needs framework with the Crépon et al. (1998) CDM model in order to track down the impact of family firms' funding gaps on innovation input and outcome. We, thereby, adopt a novel approach to issues of selectivity and identification. Third, in contrast to other work, the system of mixed process equations (Roodman, 2009) is estimated simultaneously rather than equation by equation. Moreover, we allow for a time lag between innovation expenditures and innovation output in our model.

The remainder of the paper is structured as follows. Section 2 briefly reviews the related literature and sets out the hypotheses. Section 3 describes data and methodology. Section 4 presents estimation results and Section 5 concludes.

2 Literature Review and Hypotheses

The potentially disproportionate financial needs of family firms depend on the relation between innovation capabilities and availability of affordable funding. Long-term orientation, specific entrepreneurial spirit, high commitment and social capital may empower family firms to develop higher innovation capabilities than their non-family counterparts (Le Breton-Miller and Miller, 2006; Nordqvist and Melin, 2010; Brigham et al., 2014; De Massis et al., 2015; Chrisman et al., 2015).

However, innovation capabilities cause specific funding needs. First, such capabilities require initial innovation expenditure, specifically in R&D. Second, during the process of transforming capabilities into innovation output, additional funding may be needed. It seems to be difficult to close these innovation-related funding gaps (Mina et al., 2013; Silva and Carreira, 2012; Czarnitzki and Hottenrott, 2011; Mohnen et al., 2008; Canepa and Stoneman, 2008; Freel, 2007; Schäfer et al., 2004), but the question of whether this is true for family firms as well, has not been answered yet.

Prior research on how family ownership affects the level of investment in innovation typically finds that *FB*s underinvest in research and development (R&D) compared with *NFB*s (e.g. Duran et al., 2016; Matzler et al., 2015; Block, 2012; Anderson et al., 2012; Chen and Hsu, 2009). Classen et al. (2014) reveal that *FB*s have a higher propensity than *NFB*s to invest at all in innovation, but fall short in the amount invested.

Notwithstanding the lower input, Classen et al. (2014) show that *FB*s have a higher outcome in process innovation if innovation investment is controlled for. *FB*s perform equally in terms of product innovation, but under-perform in terms of labor productivity. Duran et al. (2016) and Chen and Hsu (2009) both argue that *FB*s have higher innovation productivity and, ultimately, a higher innovation output than *NFB*s. The issue of whether family firms have access to affordable funding is crucial for transforming input into innovation output. Surprisingly, this issue has been widely ignored in prior research that compares the respective innovation output of *FB*s and *NFB*s.

According to the financial "pecking order" firms prefer to draw on internal funds before resorting to borrowing and, finally, to external equity financing (Myers and Majluf, 1984). This ranking is caused by information deficits of firm outsiders vis-*à*-vis insiders. This information asymmetry drives a wedge between internal and external costs of capital (Stigler, 1967). Internal cash flows are the cheapest source of capital because there is no information asymmetry. Debt issuing is the second cheapest source of capital and signals strength of the firm, but lenders require a premia to account for the risk of a borrower behaving opportunistically. Equity is the most expensive source of capital because of an embedded premia compensating new shareholders for the risk of overvaluation of shares.

Firm earnings are often the primary source of income for the family. Therefore, freeing up internal cash flow for investment in innovation may be difficult (Andres, 2011). While, in principle, external financiers could close such funding gaps, prior research indicates that accessing external funds may be disproportionately difficult and expensive for family firms.

*FB*s have a strong preference for remaining independent and, therefore, may be particularly reluctant to use external funding (Peters and Westerheide, 2011; Brundin et al., 2014). Furthermore, *FB*s are typically small. Small firms suffer disproportionately from opaqueness and information asymmetry and, thus, face high borrowing costs (Petersen and Rajan, 1994, 1995; Schäfer and Talavera, 2009). Bandiera et al. (2015) and Hiebl (2012) observe that *FB*s receive private benefits from control. However, tight family control may facilitate expropriation of external financiers (Jensen and Meckling, 1976) and increase funding cost. Steijvers and Voordeckers (2009) confirm that *FB*s access to external finance a disproportionately restricted. They find that *FB*s are more likely to be required to pledge collateral and infer from this evidence that agency costs of debt are higher in *FB*s.

On the other hand, family ownership is linked with firm characteristics which have been found to ease financial access and reduce borrowing costs. Gallo and Vilaseca (1996), Ampenberger et al. (2013) and Gottschalk et al. (2014) find that *FB*s work with lower leverage than their non-family counterparts. A *FB* may have a strong incentive to keep a sufficiently secure capital structure as the owners' wealth is typically non-diversified and the ability to bear risk is, therefore, reduced. In addition, *FB*s seem to be more concerned with reputation issues than *NFB*s (Anderson et al., 2003).

Both a conservative capital structure and utility gains from control and reputation increase a firm's cost of strategic default and reduce firm insiders' opportunistic behavior against lenders and external shareholders. Such reduction of moral hazard improves financial access (Stiglitz and Weiss, 1981) and decreases the marginal cost of external funds. It also fosters long-term bank-firm relationships. The typically close relationship between a *FB* and its house bank seems to manifest its most positive effects during difficult times when bank-firm relationships are under stress (D'Aurizio et al., 2015; Crespi and Martin-Oliver, 2015).

Taking into account these considerations and the specific funding requirements of innovation capabilities, there are strong reasons to believe that *FB*s' funding gaps can be either higher or lower than those of *NFB*s. Accordingly we propose two opposite hypotheses about how *FB*s' financial needs differ from those of *NFB*s:

1. ***Ceteris paribus*, *FB*s have higher financial needs than *NFB*s**

or alternatively

2. ***Ceteris paribus*, *FB*s have lower financial needs than *NFB*s.**

To measure *fn* empirically, we employ the so-called ideal test, proposed by Hall (2005). This test suggests that the question of whether innovation-driven funding gaps (= financial needs) exist can be answered by observing what a company would do if offered additional funds. Empirically, Hypothesis 1 is confirmed and Hypothesis 2 is rejected if the coefficient of the *FB* dummy variable as a determinant of financial needs *fn* is positive and significant.

A firm's actually realized innovation input is determined by its actually available funds. While *FB*s might have, on average, higher financial needs, *FB*s with high financial need might still be constrained to invest less due to shortage of funds. The possibility of a binding funding constraint raises the immediate follow-up question of whether a potentially lower input also induces a lower level of innovation output of *FB*s (Classen et al., 2014). Important for this transformation is *innovation productivity*, which is the ratio of innovation output relative to innovation input. In the empirical application we will measure *marginal* innovation productivity, which is the effect of increasing the input by one unit on innovation outcome. One theoretical explanation for *FB*s' higher marginal innovation productivity could be that *FB*s do not suffer as much as *NFB*s from agency problems (e.g., Chrisman et al., 2004, and Villalonga and Amit, 2006), and therefore are able to engage in innovation projects more cost efficiently. Cost efficiency of *FB*s is expected due to the alignment of owner-managers' interests, implying a more conservative and careful resource allocation relative to that of *NFB*s (Jensen and Meckling, 1976). Accordingly, we hypothesize:

3. ***Ceteris paribus*, *FB*s have a higher marginal innovation productivity than *NFB*s.**

Higher marginal innovation productivity means that one unit of innovation input generates, on average, more innovation output. Hypothesis 3 is supported if the coefficient of the interaction effect between *I* and *FB* in the second equation is positive and significant. While *FB*s might have, on average, a higher marginal innovation productivity, *FB*s with high *fn* might still generate less innovation output because of financial restrictions. Thus, we hypothesize:

4. ***Ceteris paribus*, *FB*s with *fn* have less innovation output compared to *NFB*s.**

Hypothesis 4 is supported in the empirical analysis if the coefficient of the interaction effect between *fn* and *FB* in the third equation is negative and significant.

In addition, a number of studies suggest that *FB*s tend to engage in incremental rather than more risky radical innovation projects (e.g., Naldi et al., 2007). One reason for this caution is that all of the family wealth is invested in a single firm (e.g., Andres, 2008), implying that *FB*s tend to avoid high-risk projects (e.g., De Massis et al., 2015).

Our CDM approach allows us to study firms' ability to increase productivity by generating innovation output. While market innovations and firm novelties open up new business opportunities, process innovations result in cost savings. Accordingly, either or both of these activities should increase a firm's labor productivity and value added. *FB*s are expected to be more effective in turning innovation outcomes into higher labor productivity because of a better alignment of the interests of owners and managers. These characteristics of *FB*s lead us to Hypothesis 5:

5. ***Ceteris paribus*, *FB*s generate a higher labor productivity from a given level of innovation outcomes.**

Hypothesis 5 is supported in the empirical analysis if the coefficient of the interaction effect between *FB* and *InnoOutput* in the fourth equation is positive and significant.

3 Empirical Approach

3.1 Data

The Mannheim innovation panel (MIP) is a data base used to study the effects of family ownership on funding and success of corporate innovations. Commissioned by the German Federal Ministry of Education and Research (BMBF), the Center for European Economic Research (ZEW) has been collecting data on innovation in Germany through the MIP survey since 1993. MIP is the German contribution to the annual European-wide Community Innovation Surveys (CIS), which provide essential information about new products, services, and processes, innovation input, and ways to achieve economic success with new products, services, and improved processes. We use the 2007 wave because it includes specific questions about funding sources for innovation and about whether or not the firm considers itself a family business. In 2007, approximately 4,000 German firms responded to these questions. In order to analyze the long-term impact of financial needs and innovation expenditure in 2006 have on innovation outcomes and productivity two years later, we merged this data with the survey from 2009.[3]

We use survey questions that allow us to distinguish between family firms and non-family firms, questions that provide information on a firm's innovation capability and financial constraints/financial needs and questions that inform us about innovation expenditures (input), innovation output and performance (labor productivity). The variables used in our empirical model are listed in Table

[3]For an overview of state-of-the-art dynamic approaches of R&D and innovation modelling, see Peters et al. (2016). As information on financial need and family ownership is only available for year 2006, we cannot apply a dynamic panel model in this context.

1. Company size is measured using seven categories based on the number of employees (Table 2). Industry is a categorical variable that determines the economic sector of a firm (Table 3).

Variable *fn* is derived from two survey questions indicating what firms would do with exogenously provided additional funds. The first question reads: *Suppose your company would unexpectedly have additional own funds of 10% of the last annual turnover, would you use the funds for A. implementation of (additional) investment projects, B. implementation of (additional) innovation projects, C. accumulation/creation of reserves, D. distributions to owners (incl. repayment of shareholder loans), E. decrease of liabilities (for example, repayment of bank loans, accounts payables etc.), F. No assessment possible.* "10% of the last annual turnover" refers to own funds that are less expensive than external loans and equity. By selecting option *B* the firm indicates that it expects the margin profit to be higher from innovation projects than from the other alternatives, such as realizing other investments (*A*), insurance against the risk of unexpected funding requirements (*C*) and reduction of expensive external funding (*D* and *E*).

The second question asks for the respondent's readiness to use external loans for innovation purposes: *Suppose your company would be offered a credit of the same amount at a relatively low interest rate, instead of the unexpected additional own fund, would your company still conduct the same investment and innovation projects? A. yes, implementation of investments likely, B. yes, implementation of innovation projects likely, C. no, not likely, D. no assessment possible.*

Double selection of *B* implies that this firm has a positive financial need for a cheap loan even though the offered borrowing alternative is more expensive (e.g. Myers and Majluf, 1984 and Stigler, 1967) and less preferred (Peters and Westerheide, 2011) than the own additional funds offered in the first question. This is because the firm will double-select if, and only if, available innovation capabilities relative to own internal funds establish a funding gap, but available external bank loans are more expensive compared with the offered cheap loan. In contrast, firms with access to a cheaper loan than the one offered in question 2 have only a positive *fn* for additional internal funds (offered in question 1) but a zero *fn* for the offered loan (see also Figure 1 in the Appendix). Accordingly, we define three different levels of *fn*, ranging from zero (*B* neither selected in question 1 nor 2) to two (double selection of *B*): $fn \in [0,1,2]$.

Another pillar of the empirical framework rests on defining innovation capability (IC) as the firm's capacity to generate innovation. We proxy *IC* with four variables: proportion of staff with a university degree (*UD*), training expenditures over total turnover (*TE*), R&D expenditures over total turnover (*RD expenditure*), and how often the company engages in R&D (*RD engagement*). The latter variable has three levels: *continuously, occasionally*, or *never*.

Finally, innovation output is measured using three dimensions: (1) the share of turnover from market novelties, (2) the share of turnover from firm novelties and (3) average cost reductions per unit caused by process innovations. Labor productivity is represented by the variable value added over employees.

The descriptive statistics of the chief characteristics of our sample are shown in Tables 2 - 10. *FB*s are, on average, smaller than *NFB*s (Table 2); however, both types of firms are similarly likely to have some type of innovation outcome (e.g., product or process innovation, Table 4). While *FB*s can be found in almost all industries, the fraction of *FB*s in technical and business consulting, as well as in financial industries (banks, insurance), is significantly lower compared to *NFB*s (Table 3). On the other hand, more *FB*s are found in low- to medium-tech manufacturing such as wood and paper, plastics, food and tobacco.

Table 5 shows the fraction of *FB*s and *NFB*s that experience difficulties in conducting innovation projects. *FB*s are more likely to mention that innovation projects have not been started or cancelled after start because of high economic risk or high costs. *FB*s also mention to a larger extent that lack of sufficiently qualified staff is a hampering factor for innovation.

Table 6 displays specifically summary statistics for *fn*, the variable of main interest. *FB*s have, on average, higher *fn*, and thus would engage in more innovation projects if additional cash or cheap loans were available. While the first category, "low financial needs" ($fn = 1$) is similar for *FB*s and *NFB*s (around 35% for both), the second category, "higher financial needs" ($fn = 2$), shows a greater difference between *FB*s and *NFB*s (26% vs. 19%).

Table 7 reveals that *FB*s have, on average, only about half the R&D expenditures of *NFB*s (expressed as a share of turnover). However, the fraction of *FB*s that never engage in R&D is similar to that of *NFB*s (about two-thirds of both types never engage in R&D). *FB*s that engage in R&D are less often engaged *continuously* than *NFB*s, but rather on a more *occasionally* basis. R&D represents a cost to firms, and perhaps because they are simply more cost avoidant than *NFB*s, *FB*s invest less than *NFB*s in knowledge generation.

Table 7 also shows that *FB*s employ a significantly lower share of staff with a university degree *UD* (15% vs. 25%). This lower level of skilled employees appears to be related to the fact that *FB*s (compared to *NFB*s) are less prevalent in knowledge-intensive services. Although *FB*s have slightly lower innovation input I (4.1% vs. 5.3%), they seem to produce the same amount of innovation outputs, such as share of turnover with market novelties, firm novelties, and cost reductions via process innovations (Table 4). However, one can also see that *FB*s, on average, have a lower labor productivity, measured as value added per employee.

Tables 8 and 9 highlight the aspect of selection of firms with respect to innovation activities. Among firms that do not have innovation expenditures only 9.4% of *NFB* and 16.1% of *FB* report high *fn*, while about two-thirds of firms do not. On the other hand, among firms that have innovation expenditures, 24.9% of *NFB* and about 33% of *FB* report high *fn*. This implies that they could do more innovation projects if they had the funding. Note also that this difference between *FB*s and *NFB*s is statistically significant. Table 9 also shows that even firms without innovation expenditures might have innovation outcomes 2 years later. However, this is not very common considering that for market novelties this applies only less than 2% of the firms. On the other hand, one can learn from Table 9 that even firms with positive innovation expenditures do not necessarily have innovation outcomes. One example is $InnoFirm$ where about 26% of the firms having innovation expenditures do not possess firm novelties 2 years later.

Table 10 displays firms' financing sources for innovation and regular investment revealing that for innovation funding, internal cash is the most important source for both *FB*s and *NFB*s: 60.8 % for *FB*s and 60.1 % for *NFB*s. Note that a statistical test regarding the difference turns out to be insignificant, thus, *FB*s and *NFB*s depend equally on internal funds. For *FB*s, the second most important funding source is overdraft credits, which are presumably more expensive than earmarked bank loans. In contrast to *FB*s, the second most important funding source for *NFB*s is public allowances, which are low cost funds. For *FB*s, shareholder loans, bank credits and overdraft credits are more relevant sources for funding innovation, whereas public subsidies are less frequently mentioned by this type of firm. Overall, this pattern of funding sources implies that *FB*s incur higher financing costs, on average, to fund innovation.

In sum, the descriptive statistics reveal that *FB*s tend to have fewer employees with a university degree, significantly lower research and development expenditures, but a similar level of innovation expenditures. Although generally speaking, the innovation capabilities of *FB*s appear to be lower (given less focus on R&D and fewer employees with university degree), they seem to achieve similar levels of innovation output (relative to sales) in comparison to *NFB*s.

3.2 Empirical Model

A recursive system with unidirectional dependency among the endogenous variables is defined that consists of four equations: (1) financial need, (2) innovation expenditure (= innovation input), (3) innovation output (= market, firm, or process innovation), and (4) labor productivity. The major advantage of specifying a recursive system is that we do not need to consider the endogeneity issue of right-hand side dependent variables from previous equations in the system. In fact, in a recursive system, the estimation can be based on the observed values of endogenous variables and not on predicted values (Roodman, 2009, 2014).

The first equation describes financial need (*fn*) as a function of the firm's innovative capability (*IC*), family firm status ($FB \in [0,1]$), and control variables. As explained above, *fn* is an ordered categorical variable with $fn \in [0,1,2]$ and is therefore formulated as an ordinal probit equation. The second equation describes innovation input (*I*), which depends on financial need, family firm status and controls. Following previous literature, we control for company size, industry, whether the firm is located in West or East Germany, the equity ratio in 2005, and the return on sales as a proxy for internal financing capacity and whether or not the firm belongs to a group. The dependent variable of the third equation (*InnoOutput*) is defined in terms of one of three possible innovation outputs. *InnoOutput* is measured either by (1) the share of turnover from market novelties (*InnoNovel*), (2) the share of turnover from new or clearly improved products (*InnoFirm*),[4] or (3) the reduction of average costs by means of process innovations (*InnoProcess*). All variables for the third and fourth equation of the model are obtained from the 2009 survey in order to take into account the time lag between investment in innovation and innovation outcome in terms of sales. The left-hand side of the fourth and last equation is the logarithm of firm's labor pro-

[4]The variables *InnoNovel* and *InnoFirm* are fractions and thus censored with a lower-bound value of 0.

ductivity ($\log LP$) in year 2008 explained by innovation output, family firm status (*FB*) and control variables such as the capital intensity of the firm. We deviate from Classen et al. (2014) and use value per employee instead of sales per employee as labor productivity measure. Value added has the advantage of being a better performance measure compared to sales.[5] As mentioned above, these four equations constitute a recursive equation system and the errors can be correlated across equations:

$$\begin{aligned}
fn_{2006i} &= f(IC_k, FB, controls) + \epsilon_i &(1)\\
I_{2006i} &= f(fn_i, FB, fn_i \times FB, controls) + \upsilon_i &(2)\\
InnoOutput_{2008i} &= f(I_i, FB, I_i \times FB, fn_i, fn_i \times FB, controls) + \omega_i &(3)\\
\log LP_{2008i} &= f(InnoOutput, FB, InnoOutput \times FB, fn_i, controls) + \eta_i &(4)
\end{aligned}$$

where ϵ_i, υ_i, ω_i and η_i are iid error terms from a multivariate normal distribution, and IC_k denote the innovation capability controls, *fn* financial need, *FB* the family firm status dummy variable and I innovation expenditure.[6]

CMP can be interpreted, from a computational point of view, as a seemingly unrelated regressions (SUR) estimator and its parameter can be consistently estimated in a recursive system equation by equation using observed values of right-hand side endogenous variables. Nonetheless, the joint estimation of the full equation system takes into account the full covariance structure and is therefore more efficient (Roodman, 2009, 2014).

Note that the estimate for variable FB in Equation (1) provides a test of Hypothesis 1 and Hypothesis 2. In Equation (3) the interaction effect $I_i \times FB$ corresponds to Hypothesis 3, while the interaction term $FB \times fn$ allows to confirm or

[5]The disadvantage of value added is that this information is less frequently available for firms in comparison to sales.

[6]We employ David Roodman's CMP (conditional mixed processes) procedure implemented in STATA for the estimations (Roodman, 2009, 2014). The method has the advantage of allowing for mixed processes; that is, it permits different types of dependent variables in the system (binary, censored, interval, and continuous variables). It also allows parameters to be fixed or random, and it does not exclude missing values listwise, but conditions on each available observation and estimates simultaneous equation systems using maximum likelihood (ML). For an alternative estimation approach, see Baum et al. (2015).

reject Hypothesis 4. Finally, the interaction term *InnoOutput* $\times$ FB in Equation 4 provides a statistical test of Hypothesis 5.

4 Results

4.1 Estimation Results

We now turn to the results of the econometric estimation, which are shown in Table 11. The fact that the ρ coefficients reported at the end of Table 11 are significant in a number of cases means that the error terms of equations are correlated and thus estimation as a system of equations is appropriate. Equation (1)'s estimates reveal that the likelihood for a positive financial need is positively related to innovation capability *IC*. *FBs* are more likely to have high fn since the coefficient of *FB* is positive. The positive sign confirms Hypothesis 1 and is in line with Hottenrott and Peters (2012).

Increase in equity capital and *Overdraft credits* are more significant than other funding sources, indicating that firms which use particularly expensive outside finance, are more likely to have gaps in funding innovation projects. Issuing equity may indicate that innovation risks are too high to be financed by banks (e.g. Brown et al., 2012). Expensive *Overdraft credits* may be used if firms face particularly severe borrowing restrictions or have a strong preference for independency (Peters and Westerheide, 2011).

Marginal effects from equation (1) are displayed in Table 12. Model (A) shows that among the indicators of innovative capability IC in our model, investment in training employees, is the indicator that raises the probability of having a funding gap the most. A one unit change in the proportion of training expenditures over turnover increases the probability of having high financial need, i.e. *fn*$=2$, by 0.435 (Table 12). Firms that have increased equity or that use overdraft credits have a high probability of having funding gaps.

In Equation (2), the positive and significant coefficient on *fn* reveals that firms with high financial need are more likely to have higher innovation expenditures. The coefficient of *FB* is insignificant, implying that, if all other influences are controlled for, the family businesses in the sample spend, on average, the same amount on innovation as do other firms. In addition, the coefficient of the interaction term $fn \times FB$ is significant and negative. This means that the group of *FB*s that have funding gaps spend less on innovation.

The results for the third and fourth equation show that the outcome of the knowledge production function *InnoOutput* is significantly explained by the amount of innovation input (*I*). There is a consistent pattern of positive significant coefficients for all three types of innovation outputs: *InnoNovel*, *InnoFirm* and *InnoProcess*.

*FB*s translate innovation input into market novelties (*InnoNovel*) to a significantly smaller extent than do *NFB*s, as shown by the negative and significant coefficient of the interaction term *FB*×*Innovation input (I)* in Equation (3). Thus, *FB*s' marginal innovation productivity in terms of market novelties is lower, and Hypothesis 3 is not supported. Similarly, the significant and negative coefficient on the interaction term in Model (C) (*InnoProcess*) shows that *FB*s are on average less efficient in turning innovation input (I) into cost-reducing process innovations; again, Hypothesis 3 is not supported for process innovations. Also Hypothesis 4 is not supported as we find no evidence that *FB*s with financial needs have on average lower innovation output.

The results for the fourth equation, $\log LP$, reveal that, in contrast to the descriptive statistics shown in Table 4, and in contrast to the results reported in Classen et al. (2014), *FB*s do not have a significantly lower labor productivity. This holds when controls, in particular the firm's capital intensity, are included in Equation (4). Furthermore, we do not find a significant difference between *FB*s and *NFB*s with respect to a higher effectiveness of *FB*s in turning innovation output into higher productivity. Thus, we cannot confirm Hypothesis 5.

Overall, we find econometric support that the lower R&D and innovation expenditures of *FB*s, compared to *NFB*s, is caused by structural differences. *FB*s are, on average, smaller and more prevalent in low- to medium-tech industries and relatively less represented in IT and business services. Accordingly, the share of employees with university degrees is smaller in *FB*s. They are also more likely to have funding gaps for innovation projects. We find that innovation expenditure (input) are significantly lower for *FB*s with financial needs. However, we do not find evidence that innovation output of *FB*s are lower than that of *NFB*s once we control for these structural differences. Conversely, *FB*s appear to be less able to transform innovation expenditures into market novelties and process innovations, as indicated by the significant negative interaction effects in Equation (3).

On the other hand, the owners' involvement in the family firm leads to stronger cost sensitivity for innovation projects. The finding that the significantly lower R&D expenditure of *FB*s yields the same amount of innovation output is consistent with this explanation. We also find some evidence that *FB*s have a somewhat stronger focus on incremental innovation than do *NFB*s. Remember that *FB*s are rarely found in R&D-intensive high-tech sectors. Prior research on hampering factors for innovation reveals that *FB*s are more risk averse in terms of high costs or economic risk than *NFB*s and, thus, are perhaps more reluctant to become involved in industries characterized by fast-changing technology, for example, the pharmaceutical or electronics sectors. As a result, *FB*s are more prevalent in traditionally more stable industries. In summary, Hypothesis 1 is supported by the empirical findings, while Hypothesis 2, Hypothesis 3, Hypothesis 4 and Hypothesis 5 are not.

According to our results, *FB*s are not very different from *NFB*s in terms of innovation inputs and outputs, but are quite different in terms of perceived funding gaps for innovation projects.

Therefore the first question, whether family ownership matters for access to external funding of innovation, can be clearly answered with yes. The descriptives reveal that although both *FB*s and *NFB*s mainly use internal funds for financing innovation, *FB*s rely more heavily on external funds, such as earmarked bank loans and overdraft credits. As, in particular, the latter is more expensive financing, it is apparent that *FB*s have, on average, higher external financing costs for innovation.

In sum, the estimation of the recursive equation system suggests that *FB*s are more likely to have a financial need for innovation. This implies that *FB*s are more likely to have projects that they could conduct if additional funds were available.

The second question, whether family ownership matters for success of corporate innovation, does not have as clear-cut an answer as the first question. First, the econometric results show that, ceteris paribus, *FB*s with financial need invest significantly less in innovation. However, interestingly, the results show that these firms do not have lower levels of innovation output. Because the overall level of innovation outcome of *all FB*s do not differ from *NFB*s, one could draw the conclusion that family ownership does not matter for success of corporate innovation. Second, however, the econometric results also reveal that *FB*s would increase innovation sales with market novelties significantly less than *NFB* if investments in innovation increase. Thus, the econometric results show that *FB*s are less able to transform innovation investment into higher innovation sales or into cost reductions (process innovation). In conclusion, we find that *FB*s demonstrate on average a significantly lower *marginal innovation productivity*. Therefore the second question can also be answered with yes. While family ownership does not matter much for levels of innovation input and output, it matters for the productivity of innovation expenditures in terms of radical and process innovations. The explanation of this result is that *FB*s do not have a comparative advantage in pursuing radical innovation projects, given their lower innovation capability and higher risk aversion. Accordingly, *FB*s are less prevalent in high-tech and service industries where constant innovation is required to remain competitive and viable.

4.2 Robustness Checks

We conducted a series of tests to check the robustness of our results. Following the suggestions made by the CMP procedure description, we defined *fn* as observed instead of a latent variable.[7] This means that *fn* is replaced by predicted values from Equation (1) in the system estimation. Using the predicted instead of observed values, we find that the first two equations on financial needs and innovation input remain very similar in the estimated coefficients, while *fn* is no longer significant in the third and fourth equations for innovation output and labor productivity.[8]

Furthermore, we estimated our model by using an equation-by-equation approach to investigate how the system CMP estimation affects the results.[9] We find that *FB* remains positive and significant in the financial need equation, and that *fn* is significant and positive for the innovation input equation for all three indicators for the innovation output. The interaction term between *fn* and *FB* is insignificant in the single-equation model, similarly there is no support for Hypothesis 3 according to the insignificance of the interaction between *FB* and *I*. This observation proves that it is important to estimate the entire system instead of taking an equation-by-equation approach.

[7] Again, as mentioned above, in a recursive system of equations the estimations can be based on observed values of right-hand side endogenous variables, not on instrumented ones.

[8] Note that the explanation for this change of significance is that predicted *fn* is more strongly correlated with the other explanatory variables and therefore becomes less significant when instrumented.

[9] Again, the results are available from the authors upon request.

5 Conclusions

The aim of our paper is to investigate whether family ownership matters for funding and success of corporate innovation. We utilize the approach suggested in Hottenrott and Peters (2012) for measuring latent financial need and formulate a recursive system of equations in the spirit of CDM (Crépon et al., 1998). We address the issue of selectivity with an equation that explains the likelihood of having a funding gap for innovation. We apply this framework to the Mannheim innovation panel including the years 2006 and 2008.

In fact, the evidence shows that family ownership matters. Despite the overall similar level of innovation inputs and innovation outcomes for *FB*s and *NFB*s, we find that *FB*s are more likely to have latent financial needs, that is they would engage in more innovation if they had the funding for it. On the other hand we find that *FB*s have a lower marginal innovation productivity. This implies that when compared to *NFB*s, an increase of innovation expenditures by *FB* will lead to a lower increase of innovation outcome, especially in regard to market novelties. This could be caused by the disproportionate funding gap for *FB*s, or it might be related to *FB*s' comparative disadvantage in radical innovation due to lower innovation capability in combination with higher risk aversion.

From a policy perspective our results may provide some interesting insights into the concern over declining innovation on the part of small and medium-sized enterprises, most particularly in the case of family businesses (so-called German "Mittelstand"). The data indicate that when compared to other firms, *FB*s are more likely to mention high economic risk, high innovation costs, and insufficiently qualified personnel as the main obstacles to engaging in innovation. Surprisingly, and in conflict with the finding that they perceive having high financial needs, *FB*s are no more likely than other firms to mention insufficient internal or external funding as an obstacle to innovation. Therefore, whether relaxing financial constraints for family businesses (and, potentially, other types of businesses) might boost innovation performance is a topic worthy of further research.

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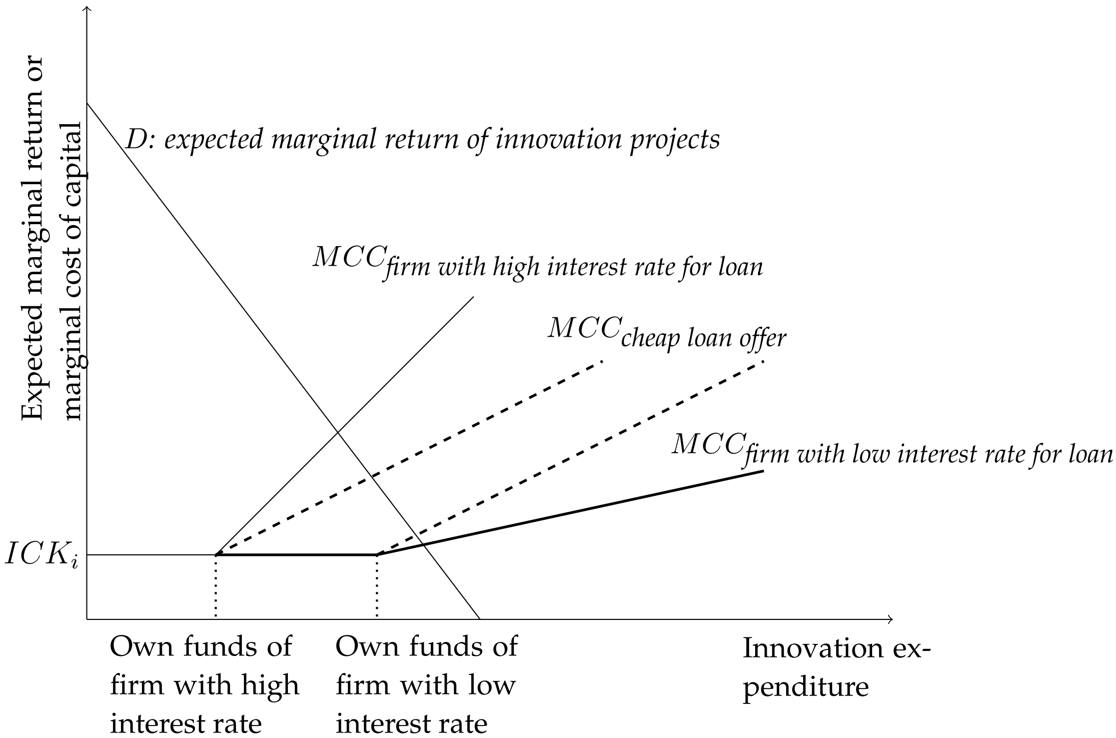
Appendix

Figure

Tables

Definitions and Descriptive Statistics

Figure 1: **Illustration of different degrees of financial need**



First question: the firm with high marginal external funding costs (MCC) (*high interest rate for loan*) takes option *B* in the first question. The firm with low MCC (*low interest rate for loan*) does the same because the cost of offered additional internal funds (ICK) are lower than the firm's interest rate for an external loan. *Second question*: the firm with high MCC (*high interest rate for loan*) selects option *B* also in the second question since the interest rate for the *cheap loan offer* is lower then the high interest rate for taking an external loan. In contrast, the firm with low MCC (*low interest rate for loan*) does not select option *B* in the second question since the interest rate for the cheap loan offer is higher then the own (very) low interest rate for an external loan. This firm has a funding gap of zero and, therefore, zero financial need for the additional cheap loan offered in question 2. Accordingly, this firm with the low MCC has lower financial need ($fn = 1$) than the firm with the high MCC ($fn = 2$). Note that the result, the firm with low MCC (*low interest rate for loan*) has zero funding gap with respect to question 2 is independent of whether this firm has lower or higher own funds (lower or higher innovation capabilities D, lower or higher internal cost of capital ICK_i).

Table 1: Variable definitions

Variable name	Definition
FB	Family firm
NFB	Non-family firm
fn	Financial need with $fn \in [0,1,2]$
IC	Innovation capability: *UD*, *TE*, *RD expenditure* and *RD engagement*
UD	Percentage of employees with university degree (%)
TE	Share of training expenditures over total turnover (%)
RD expenditure	Research and development (R&D) expenditure over turnover (%)
RD engagement	Research and development (R&D) frequency of engagement: *Continuously*, *occasionally* or *never*
I	Innovation input: innovation expenditure over turnover (%)
InnoOutput	Innovation output: *InnoNovel*, *InnoFirm* and *InnoProcess*
InnoNovel	Share of turnover from market novelties (%)
InnoFirm	Share of turnover from firm novelties (%)
InnoProcess	Reduction in average unit cost by process innovations (%)
$\log LP$	Natural logarithm of value added over number of employees)
Controls	Industry, size classes, located in West or East Germany, equity ratio in 2005, return on sales, belonging to a company group, capital stock per employee
Constraints	High economic risk (C1), high cost (C2), insufficient internal funding (C3), external funds (C4) or qualified staff (C5)
Size classes	Company size by number of employees
Return on sales	Return on sales in the last two years
Export-orientation	Geographic activities: local/regional turnover, national, EU/EFTA, outside EU turnover (exports)
Innoexp	Total innovation expenditure over turnover (%) (innovation intensity)
Industry	NACE 2-digit industry code (Rev. 1), 21 industries

Table 2: Size classes (%), year 2006

	NFB	*FB*
0 < employees $\leq$ 19	30.7	37.3
20 $\leq$ employees $\leq$ 49	17.5	19.7
50 $\leq$ employees $\leq$ 99	13.1	14.4
100 $\leq$ employees $\leq$ 249	14.9	13.7
250 $\leq$ employees $\leq$ 499	9.1	6.9
500 $\leq$ employees $\leq$ 999	5.6	3.6
$\geq$ 1000 employees	9.1	4.4
Total (%)	100.0	100.0
# obs	2,029	2,665
χ^2-test	77.8***	
p-value	0.000	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$,
FB: Family Business, *NFB*: Non-family Business

Table 3: Industry (%), year 2006

	NFB	*FB*
Mining	7.9	3.2
Food, tobacco	1.7	6.0
Textiles	2.0	4.1
Wood, paper	1.5	4.6
Chemicals	3.6	3.9
Plastics	1.7	5.4
Glass, ceramics	1.8	3.9
Metals	5.4	8.6
Machinery	5.4	6.8
Electrical equipment	4.0	6.6
Medical instruments	3.2	2.5
Transport equipment	4.1	5.6
Furniture	8.7	3.0
Wholesale	3.7	5.5
Retail, automobile	8.0	8.8
Transport, communications	4.8	4.9
Banking, insurance	6.0	2.7
IT, telecom	8.0	2.2
Technical services	10.6	5.1
Firm-related services	4.5	2.3
Other services	3.3	4.2
Total (%)	100.0	100.0
# obs	1,891	2,457
χ^2-test	464.9***	
p-value	0.000	

Notes: see Table 2

Table 4: Innovation outputs and labor productivity (means and standard deviations), year 2008

	InnoNovel		*InnoFirm*		*InnoProcess*		log*LP*	
	NFB	*FB*	*NFB*	*FB*	*NFB*	*FB*	*NFB*	*FB*
mean	2.2	1.9	10.6	10.2	1.4	1.6	-1.9	-2.1
sd	8.4	6.5	20.1	19.2	4.5	4.6	0.8	0.7
# obs	774	957	767	956	716	873	769	959
t-test	0.9		0.4		-0.9		6.3***	
p-value	0.4		0.7		0.4		0.0	

Notes: see Table 2

Table 5: Fraction of firms (%) experiencing constraints for innovation projects, year 2006

Innovation constraint[a]	NFB	FB	t-test	# obs
High economic risk (C_1)	17.5	19.9	-1.98^{**}	3,988
High cost (C_2)	17.3	20.4	-2.44^{***}	3,896
Insuff internal funding (C_3)	11.7	12.4	-0.71	3,911
Insuff external funds (C_4)	9.1	10.2	-1.06	3,905
Insuff qualified staff (C_5)	7.1	9.6	-2.68^{***}	3,721

Notes: see Table 2

[a]Innovation project not started or cancelled because of constraint

Table 6: Share of firms (%) with latent financial need (*fn*) for innovation projects, year 2006

	NFB	*FB*
Without financial need *fn*=0	45.8	38.7
Low financial need *fn*=1 (cash)	35.7	35.0
High financial need *fn*=2 (cash and loan)	18.5	26.3
Total (%)	100.0	100.0
# obs	827	1,208
χ^2-test	19.1***	
p-value	0.000	

Notes: see Table 2

Table 7: Innovation capability and innovation input (I), year 2006

	UD		TE		RD expendit.		RD engagement			I	
	NFB	*FB*	*NFB*	*FB*	*NFB*	*FB*		*NFB*	*FB*	*NFB*	*FB*
mean	24.8	15	1.5	1.7	2.6	1.3	*Nev*	66.5	66	5.3	4.1
sd	25.9	21.1	4.2	5.4	13.6	6	*Con*	22.1	19.7	17	12
							Occ	11.4	14.3		
# obs	1,855	2,387	1,643	2,097	1,815	2,389		2,011	2,639	1,715	2,324
t-test	13.6***		-0.77		4.34***		χ^2-test= 10.73***			2.55**	
p-value	0.000		0.44		0.000		0.005			0.011	

Notes: see Table 2, *Con: continuously*, *Occ: occasionally*, *Nev: never*

Table 8: Financial need and innovation expenditure *I*, fraction of firms (%), year 2006

	I=0		*I>0*	
	NFB	*FB*	*NFB*	*FB*
Without financial need *fn=0*	66.6	63.6	31.3	22.3
Low financial need *fn=1* (cash)	24.0	20.3	43.8	44.6
High financial need *fn=2* (cash and loan)	9.4	16.1	24.9	33.0
Total (%)	100.0	100.0	100.0	100.0
# obs	341	478	486	730
χ^2-test	8.3***		15.5***	
p-value	0.000		0.000	

Notes: see Table 2

Table 9: Fraction of firms (%) with innovation expenditure *I* (>0 or =0) (year 2006) and innovation output (>0 or =0) (year 2008)

	InnoNovel				*InnoFirm*				*InnoProcess*			
	I=0		*I>0*		*I=0*		*I>0*		*I=0*		*I>0*	
	NFB	*FB*	*NFB*	*FB*	*NFB*	*FB*	*NFB*	*FB*	*NFB*	*FB*	*NFB*	*FB*
InnoOutput=0	98.3	98.1	87.4	88.5	92.8	94.1	73.4	76.3	95.0	94.7	77.0	78.3
InnoOutput>0	1.7	1.9	12.6	11.4	7.2	5.9	26.6	23.6	5.0	5.3	23.0	21.6
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
# obs	1,146	1,398	883	1,267	1,146	1,398	883	1,267	1,146	1,398	883	1,267
χ^2-test	0.3		0.6		2.0		2.4		0.1		0.6	
p-value	0.6		0.4		0.2		0.1		0.7		0.5	

Notes: see Table 2. *I* refers to 2006, while *InnoOutput* refers to 2008.

Table 10: Importance of financial sources for investment and innovation (%), year 2006

Source	**Investment**			**Innovation**		
	NFB	*FB*	*t*-test	*NFB*	*FB*	*t*-test
Internal cash flow	73.0	67.6	3.77***	60.1	60.8	−0.41
Increase in equity capital	6.4	6.1	0.45	4.7	3.9	1.10
Shareholder loans	10.0	13.1	−3.03***	6.1	8.3	−2.36***
Bonds	0.4	0.5	−0.12	0.7	0.5	0.68
Overdraft credits	16.3	25.2	−6.95***	9.0	15.8	−5.50***
Earmarked bank credits	21.3	32.0	−7.73***	5.7	9.7	−3.95***
Public loans	9.5	10.4	−1.00	4.4	5.1	−0.92
Public allowances	14.0	8.6	5.50***	12.1	7.9	3.86***
Other sources	1.1	1.8	−1.79*	1.4	0.8	1.49

Notes: see Table 2

Estimation Results

Table 11: CMP estimation of recursive system

	Model (A) ***InnoNovel***	Model (B) ***InnoFirm***	Model (C) ***InnoProcess***
Equation 1: Financial need (*fn*) (yr 2006)			
Family business (*FB*)	0.263***	0.265***	0.263***
	[0.076]	[0.076]	[0.076]
Employees with university degree (*UD*)	0.285	0.337*	0.268
	[0.185]	[0.185]	[0.184]
Training expenditures (*TE*)	1.638**	1.583**	1.651**
	[0.759]	[0.750]	[0.758]
Continuous R&D	0.462***	0.476***	0.456***
	[0.099]	[0.098]	[0.098]
Occasionally R&D	0.372***	0.368***	0.368***
	[0.099]	[0.099]	[0.099]
Belongs to group	-0.037	-0.017	-0.027
	[0.084]	[0.083]	[0.083]
Location East Germany	-0.117	-0.124	-0.109
	[0.080]	[0.080]	[0.080]
Cash flow	0.565***	0.559***	0.585***
	[0.088]	[0.088]	[0.088]
Increase in equity capital	0.541***	0.542***	0.572***
	[0.157]	[0.156]	[0.158]
Credits loans	0.223*	0.244*	0.211*
	[0.126]	[0.126]	[0.125]
Bonds and notes	0.039	0.031	0.032
	[0.386]	[0.383]	[0.385]
Overdraft credits	0.389***	0.396***	0.382***
	[0.100]	[0.099]	[0.100]
Earmarked bank credits	0.370***	0.382***	0.375***
	[0.126]	[0.125]	[0.126]
Public and publicly subsidized credits	0.330**	0.336**	0.338**
	[0.140]	[0.140]	[0.140]
Public subsidies and allowances	0.16	0.166	0.158
	[0.115]	[0.114]	[0.115]
Other sources	0.487	0.452	0.470
	[0.357]	[0.355]	[0.356]
# obs	1,190	1,190	1,190
Equation 2: Innovation input (*I*) (yr 2006)			
Financial need (*fn*)	6.742***	6.679***	6.614***
	[1.200]	[1.205]	[1.203]
Family business (*FB*)	0.008	-0.346	-0.114
	[1.409]	[1.432]	[1.414]

. . . continued

	Model (A) ***InnoNovel***	Model (B) ***InnoFirm***	Model (C) ***InnoProcess***
Financial need (*fn*)	-2.482**	-2.097*	-2.319*
× Family business (*FB*)	[1.221]	[1.246]	[1.228]
Equity ratio in 2005	0.039**	0.043**	0.041**
	[0.018]	[0.019]	[0.018]
Return on sales last 2 years	-0.325	-0.407	-0.235
	[0.254]	[0.282]	[0.264]
Constant	-4.405	-4.14	-4.681
	[3.328]	[3.356]	[3.340]
# obs	1,400	1,400	1,400
Equation 3: Innovation output (*InnoOuput*) (yr 2008)			
Family business(*FB*)	0.223	-2.676	-0.563
	[0.851]	[2.153]	[0.644]
Innovation input (I)	0.215***	0.453	0.140***
	[0.050]	[0.316]	[0.047]
Financial need (*fn*)	1.127	4.931**	1.224*
	[0.739]	[2.348]	[0.640]
Financial need (*fn*) × Family business (*FB*)	0.277	2.644	0.934
	[0.795]	[1.867]	[0.615]
Innovation input (I) × Family business (*FB*)	-0.146***	-0.110	-0.073**
	[0.046]	[0.125]	[0.035]
Constant	2.08	3.417	-1.066
	[1.917]	[4.822]	[1.493]
# obs	643	645	585
Equation 4: Labor productivity $\log LP$ (yr 2008)			
Family business(*FB*)	-0.040	-0.036	-0.102
	[0.065]	[0.074]	[0.072]
Financial need (*fn*)	-0.121*	0.051	-0.070
	[0.069]	[0.086]	[0.080]
Innovation output (*InnoNovel,*	0.031**	-0.013*	0.027
InnoFirm, InnoProcess)	[0.015]	[0.008]	[0.029]
Family business (*FB*) × *InnoOutput*	0.002	-0.004*	0.007
	[0.007]	[0.002]	[0.010]
Log capital per employee	0.113***	0.119***	0.137***
	[0.019]	[0.018]	[0.020]
Regional or local sales	-0.094	-0.097*	-0.108
	[0.059]	[0.058]	[0.066]
National sales	0.100	0.095	0.062
	[0.075]	[0.075]	[0.079]
EU and EFTA sales	-0.088	-0.101	-0.035
	[0.074]	[0.074]	[0.083]
Outside EU/EFTA sales	0.209***	0.233***	0.230***

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	Model (A) ***InnoNovel***	Model (B) ***InnoFirm***	Model (C) ***InnoProcess***
	[0.072]	[0.071]	[0.083]
Location East Germany	-0.324***	-0.336***	-0.296***
	[0.060]	[0.060]	[0.066]
Constant	-1.478***	-1.395***	-1.239***
	[0.202]	[0.202]	[0.209]
# obs	428	425	380
Parameters $\operatorname{atanh}\rho$ and $\ln\sigma$[c,d]			
$\ln\sigma_2$	2.851***	2.852***	2.852***
	[0.019]	[0.019]	[0.019]
$\ln\sigma_3$	2.004***	2.935***	1.699***
	[0.029]	[0.033]	[0.036]
$\ln\sigma_4$	-0.542***	-0.504***	-0.566***
	[0.097]	[0.127]	[0.087]
$\operatorname{atanh}\rho_{12}$	-0.133**	-0.143***	-0.136**
	[0.055]	[0.055]	[0.055]
$\operatorname{atanh}\rho_{13}$	-0.048	-0.178**	-0.117
	[0.064]	[0.081]	[0.078]
$\operatorname{atanh}\rho_{14}$	0.131	0.028	0.083
	[0.123]	[0.126]	[0.134]
$\operatorname{atanh}\rho_{23}$	0.096	-0.069	-0.183
	[0.108]	[0.345]	[0.154]
$\operatorname{atanh}\rho_{24}$	-0.362***	-0.003	-0.233***
	[0.092]	[0.133]	[0.080]
$\operatorname{atanh}\rho_{34}$	-0.403*	0.615**	-0.231
	[0.220]	[0.243]	[0.289]
Industry effects (in all equations)	Yes	Yes	Yes
Size effects (in all equations)	Yes	Yes	Yes
Total # obs system	1,756	1,753	1,746
Model *df*	144	144	144
χ^2-test	859.7	898.9	831.8
p-value	0.000	0.000	0.000

[a] Standard errors in brackets, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[b] Model (A) *InnoNovel*=share of turnover with market novelties, model(B) *InnoFirm*=share of turnover with firm novelties and model (C) *InnoProcess*=reduction of costs by process innovations

[c] $\operatorname{atanh}\rho$ and $\ln\sigma$ are transformations of parameters ρ and σ, respectively [d] $\cdot_{ij}$ stands for equations *i* and *j*

Table 12: Average marginal effects for equation (1)

	(A) Model: *InnoNovel*	(B) Model: *InnoFirm*	(C) Model: *InnoProcess*
Family business (*FB*)	0.070***	0.070***	0.070***
	[0.020]	[0.019]	[0.019]
Eastern Germany	-0.031	-0.033	-0.033
	[0.021]	[0.021]	[0.021]
Continuously R&D	0.123***	0.126***	0.126***
	[0.026]	[0.026]	[0.026]
Occasionally R&D	0.099***	0.097***	0.097***
	[0.026]	[0.026]	[0.026]
Belongs to group	-0.009	-0.004*	-0.005*
	[0.022]	[0.022]	[0.022]
Employees with university degree (*UD*)	0.076	0.089*	0.06*
	[0.049]	[0.049]	[0.045]
Training expenditures (*TE*)	0.435**	0.418**	0.408**
	[0.200]	[0.197]	[0.186]
Cash flow	0.0811**	0.0811**	0.0811**
	[0.041]	[0.041]	[0.041]
Increase in equity capital	0.150***	0.150***	0.150***
	[0.056]	[0.056]	[0.056]
Credit loans	0.053	0.053	0.053
	[0.043]	[0.043]	[0.043]
Bonds and notes	0.009	0.009	0.009
	[0.145]	[0.145]	[0.145]
Overdraft credits	0.124***	0.124***	0.124***
	[0.035]	[0.035]	[0.035]
Restricted bank credits	0.0842*	0.0842*	0.0842*
	[0.045]	[0.045]	[0.045]
Public and publicly subsidized credits	0.102**	0.102**	0.102**
	[0.049]	[0.049]	[0.049]
Public subsidies and allowances	0.0438	0.0438	0.0438
	[0.041]	[0.041]	[0.041]
Other sources	0.104	0.104	0.104
	[0.129]	[0.129]	[0.129]

Standard errors in brackets
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$