

Höwer, Daniel; Sofka, Wolfgang

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Information Externalities in Bank Based Financing for Private Innovation – Can Specialization Overcome Asymmetries?

Daniel Hoewer¹, Tobias Schmidt^{2*} and Wolfgang Sofka³

¹ ZEW Centre for European Economic Research, Mannheim, Germany

² Deutsche Bundesbank, Research Centre, Frankfurt am Main, Germany

³ Department of Organisation and Strategy, CentER, CIR, Tilburg University, Tilburg, the Netherlands

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* Corresponding author at: Deutsche Bundesbank, Economic Research Centre, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main, Germany; tobias.schmidt@bundesbank.de; Tel: +49 69 9566 3730; Fax: +49 69 9566 4026

Abstract

Investments in R&D have been identified as a cornerstone for growth and competitive advantages of firms and whole economies. We investigate the role that a firm's main bank plays for its investment in R&D. Existing literature suggests that the inherent information asymmetries of R&D projects make them hardly applicable for bank lending. We challenge this assumption by arguing that banks are heterogeneous with regard to their information processing capabilities. They can benefit from information externalities arising from industry and geographical specialization in their overall loan portfolio. We combine finance as well as innovation management and economics literature to develop this argument. We test our theoretical framework for more than 7,500 firm observations in Germany and their R&D expenditures over a five year time period. A unique database allows us to construct the overall corporate client portfolio of the main bank for each of these firms. Our results show trade-offs in the degree and nature of bank specialization. Industry specialization of a firm's main bank has a u-shaped effect on its R&D investment. Regional specialization, though, has an inverse u-shaped effect. Recommendations on optimal firm-bank combinations for fostering R&D investment can be developed based on these results.

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1 Introduction

The continuous generation of innovative products, processes and services is widely considered as the primary key for competitiveness and growth of firms as well as whole economies (e.g. Grant, 1996; Schumpeter, 1942). The major input of this innovation process is unique knowledge generated by investments in research and development. Interestingly enough, though, private firms have found it extremely difficult to obtain external capital for funding these crucial investments into their future. These shortcomings in capital markets are typically explained by the nature of R&D projects. They suffer both from information imperfections as well as asymmetries (for a comprehensive review see Hall, 2005). Information imperfections from inherent uncertainties about the technological as well as commercial viability of novel products for which no ex-ante probabilities of success exist (Amit et al., 1990). Information asymmetries arise from the fact that firms possess superior knowledge about the value of their R&D projects compared with external investors (Ahuja et al., 2005). These investors, therefore, bear the extra risk of hidden information and hidden actions. These features make it difficult for firms to rely on bank loans as their primary source of external capital for financing R&D. As a result the availability of resources for R&D is limited to internal funds or equity financing, e.g. through venture capital (e.g. Kim et al., 1998; Audretsch and Lehmann, 2004).

We challenge the assumption that all banks are equally subject to suffer from information asymmetries in financing private R&D projects. Instead we argue that information externalities (Stiglitz, 2002) originating from heterogeneous client portfolios of different banks which influence their ability to overcome information asymmetries. More precisely, we focus on a firm's main bank as its primary provider of financial services. We develop theoretical arguments for why geographical as well as industry specialization of banks allows them to evaluate the potential of R&D projects and finance them while others cannot. We ground our theoretical arguments in information economics (Stiglitz, 2002). We build on this theoretical framework by reviewing finance literature on information requirements and lending decision of banks (Rajan and Zingales, 2001) and combine it with the literature stream on the particularities of R&D investments from strategic management, innovation economics and innovation management (e.g. Hall, 2005; Levitas and McFadyen, 2009).

We test this theoretical framework empirically for more than 7800 firm observations on R&D investments in Germany between 2003 and 2007. Unique access to a database on the population of German firms and their main bank business relationship allows us to construct novel variables on the overall portfolio of each of the firm's main bank. We are able to describe the degree of this bank specialization along the dimensions of geographical as well as industry dimensions.

The results of our analyses provide important implications for both management and policy makers. First, we provide evidence for the importance of the choice of a particular main bank for a firm. We develop a profile of banks with regard to how likely they are to correctly assess

a firm's investment into new products and services. Managers can exploit this heterogeneity among banks and choose a partner bank which supports its investments into future competitive assets through R&D. Secondly, the banking industry is heavily influenced by government policy. These may take the form of regulatory intervention or even direct ownership (e.g. Porta et al., 2002). Policy initiatives with the particular focus of fostering private investment in innovation activities can include elements that make it easier for firms to obtain bank loans. Our finding can provide guidance for policy programs with this particular intent and describe a favorable bank profile.

Our preliminary results based on estimating random effects tobit models show that the relationship between a firm's R&D investment and the industry specialization follows a u-shaped trend. We suspect that highly specialized banks benefit from unique information advantages when evaluating an R&D project. Banks with low degrees of specialization in the focal firm's industry, though, may be more willing to finance R&D investment because it diversifies the risk of their overall loan portfolio. The combination of both forces results in an overall u-shaped relationship. Geographical specialization of a main bank, though, has an inverse u-shaped effect on firm's R&D investment. However, significance levels of results are lower. We suppose that this effect is due to the fact that banks require a balanced pool of information about potential returns of R&D projects. A too narrowly defined focus may leave them overly cautious while a too broad focus will not allow for the depth of information that is required.

The remainder of the analysis is structured as follows. Section 2, following this introduction, outlines our theoretical framework culminating in the derivation of hypotheses in section 3. In section 4 we present our empirical study including data, variables and methodologies. Section 5 presents the preliminary results of these analyses followed by the subsequent steps envisioned in section 6.

2 Theoretical framework

We choose information economics and related signalling theory as our main theoretical building block (e.g. Stiglitz, 2002; Ahuja et al., 2005). We will focus more narrowly on its relevance for bank financing of private R&D activities. To achieve this we combine research from finance literature on bank lending decisions (e.g. Rajan and Zingales, 2001) with the literature on knowledge production through R&D. Unique knowledge is widely accepted as a major driver for competitive advantage, growth and employment. These research streams range from strategic management (e.g. Grant, 1996) to industrial economics (e.g. Cassiman and Veugelers, 2002) as well as innovation management and economics (e.g. Kogut and Zander, 1992).

R&D investments and uncertainty

Decisions on R&D investments differ from traditional investment logic because of the nature of R&D (for a recent review see Hall, 2005 and Hall, 2009). The outcomes of R&D are generally uncertain. This uncertainty has two primary dimensions Amit et al., 1990. First, there is a substantial degree of technological uncertainty about the success of an R&D project. Materials and procedures are almost by definition new and largely untested. Probability distributions for the success of an R&D project are difficult or even impossible to predict at the early stages (Hall, 2005). Hence, investments into R&D have been linked to real options theory. In that sense, the net present value of an investment cannot be calculated ex-ante. Firms perform R&D to secure options for the future and learn about the potential outcomes during the process (e.g. Adner and Levinthal, 2004). Secondly, there is an important degree of uncertainty about whether the firm will be economically successful with its technologically new products and processes. A significant proportion of product innovations end up as economic failures because they do not meet customer needs or competitors are quick in their imitation or substitution activities eroding margins from the pioneering advantage (Dos Santos and Peffer, 1995; Gourville, 2006). These high degrees of uncertainty coincide with challenges in the items R&D investments are typically directed at. Half of all R&D expenditures finance wages for skilled scientists and engineers (Hall, 2005). Investments into physical research assets and laboratories are often times highly specific to a firm or even a project making it difficult to re-deploy, sell or use as collateral (Herrera and Minetti, 2007). R&D investments suffer therefore from a “lemons” dilemma (Akerlof, 1970): The most promising projects cannot be distinguished from the less promising ones and investors will only reward average quality. These specific features of R&D investments pose a problem for innovative firms when it comes to getting access to external finance, especially from banks. Most firms therefore rely on internal financing, i.e. out of cash flow (Hall, 2005). Several studies have shown, however, that banks have an impact on the innovation activities as well (e.g. Benfratello et al., 2008).

The role of information asymmetries and signaling in access to finance for R&D projects

The “lemons” dilemma and the various forms of uncertainty linked to R&D projects as well as the specific nature of the knowledge produced (Levitas and McFadyen, 2009) go hand in hand with information asymmetries¹ between firms and their potential investors. If no information asymmetries and adverse selection problems existed “each borrower would be charged an appropriate risk premium” (Stiglitz, 2002: 461). This is, however, not the case in practice. Hall writes “In the R&D setting, the asymmetric-information problem refers to the fact that an inventor or entrepreneur frequently has better information about the nature of the contemplated innovation project and the likelihood of its success than potential investors.” (Hall, 2009: 13). Important in this context is also that the innovation process, i.e. a process of trial and error and constant discovery, is dynamic and new information arrives frequently. This introduces a time dimension to the information asymmetry issue for the financier (see

¹ For an extensive review of the literature on the economics of information and information asymmetries see Stiglitz, 2002.

Hall, 2009) and makes overcoming information asymmetries even more difficult. Not being able to mitigate information asymmetries may have severe consequences for inventors and start-up entrepreneurs. Audretsch and Lehmann write “ [...] banks [...] may fail to provide debt when the degree of asymmetric information is too high” (Audretsch and Lehmann, 2004: 341)².

Literature has argued that the effects of the information asymmetry between innovative firms and external investors can be overcome by firms signalling the economic viability of their R&D projects e.g. through patenting (Levitas and McFadyen, 2009) or their actions (Stiglitz, 2002). For many firms and inventors signalling through patents may not be an option because “not all inventions are patentable, not all inventions are patented” (Griliches, 1990: 1669). The latter part of the quotation points to a potential hold-up problem between the firm and the investors, the inventor may not be willing to fully disclose all information, because of fear of spillovers to her competitors (Herrera and Minetti, 2007). Fear of unwanted knowledge disclosure has been found to reduce the strength and quality of the signals inventors send to investors about their projects (Bhattacharya and Ritter, 1983). Even if an inventor wants to fully disclose the relevant information vis-à-vis a potential investor the informationally opaque nature of new technologies (Rajan and Zingales, 2001) and the simple fact that the information or product is new and innovative, may reduce the strength of the signal. If investors are able to build up absorptive capacities (Cohen and Levinthal, 1989; 1990), i.e. learn to understand and evaluate innovative (and potentially highly technological) project proposals, the information asymmetries may be overcome or at least mitigated. We therefore argue below that signals will be more effective if they are directed at investors that possess advantages for processing them. These advantages can stem from technological or regional specialization. Furthermore specific banks may be characterised by institutional factors providing additional incentives for them to support growth-oriented businesses³.

Sources of finance for R&D projects

As already mentioned above, many firms rely on internal finance for their innovation and R&D projects (Hall, 2005; Kim et al., 1998; Bond et al., 1999; Haid and Weigand, 2001; Harhoff, 1998). This form of finance is particularly important for small and medium-sized enterprises (see e.g. Hao and Jaffe, 1993). When it comes to external financing of innovations⁴, venture capital financing has received a lot of attention in the literature (e.g. Gompers and Lerner, 2001; Bottazzi and Da Rin, 2002; Audretsch and Lehmann, 2004). Even the role of banks as venture capitalists have been discussed (Hellmann et al., 2008). Furthermore, Atanassov et al., 2007 find that publicly traded firms in the US rely more on equity and debt financing for their R&D projects rather than relationship financing with banks. Müller and Zimmermann, 2009 find that equity financing is particularly important for

² See also the introduction of Levitas and McFadyen, 2009 and Carpenter and Petersen, 2002, for a discussion of information asymmetries and moral hazard as reasons for market failure in innovation financing.

³ Repeated interactions as a tool to reduce information asymmetries (Hall, 2009) and issues of relationship banking will not be discussed in this literature review. We will try to control for this aspect in the empirical part of the paper, by focusing on the firms “main bank” (for details see below).

⁴ For statistics on the importance of various types of finance for innovation see Rammer, 2009 (only available in German).

R&D projects of young and innovative firms. Another form of financing innovation are public subsidies or R&D tax credits⁵. The literature on public funding of R&D is large and mainly concerned with assessing the impact of public R&D support programs (e.g. Bloom et al., 2002) and crowding out effects (e.g. Aerts and Schmidt, 2008).

The literature cited above holds that bank financing for innovation is not as important as other types of financing⁶. There is some empirical evidence, however, that banks are important for fostering innovation and growth (e.g. Benfratello et al., 2008). The literature on banks and innovation financing is still scarce. One strand of literature analyses the influence of regional banking development on innovation performance of firms located in these regions. Benfratello et al., 2008 is a good example of this literature. These authors find that the number of bank branches (relative to the population) in a region has a positive influence on the probability to introduce innovations. Another strand of literature uses micro-data on individual bank-firm pairs and their credit relationships. Herrera and Minetti, 2007 show that innovations are more likely to emerge if banks and firms have long lasting relationships. Haselmann et al., 2009 analyze differences between public and private banks. They find that firms are more likely to innovate if their main bank is a private bank.

We conclude that existing research has largely treated banks as homogeneous entities when it comes to their ability to evaluate private R&D projects (with the exception of structural features such as private versus government owned banks). We challenge this assumption by developing arguments based on information externalities originating from heterogeneous client portfolios of banks. We argue that these differences enable certain banks to overcome information asymmetries in evaluating R&D projects which consequently influences the level of R&D expenditure of its client firms.

3 Hypotheses development

Overcoming information asymmetries requires resource commitments by the bank. Boot and Thakor, 2000 distinguish between two forms of bank lending. Transaction lending is closely related to brokerage activities where it is sufficient for the bank to lend based on a standardized transaction. Relationship lending, though, requires borrower specific information in activities such as screening and monitoring (for a review see Boot, 2000). The nature of investments in R&D (as outlined above) requires relationship specific investments by the bank to overcome information asymmetries. However, relationship specific lending implies also higher costs. Evaluating R&D projects and the value of the knowledge that they are supposed to produce require specialized competences. It necessitates an understanding of underlying scientific or technological mechanisms that is often times only developed in practice over time (Laursen and Salter, 2006). Hiring these experts is therefore costly. Banks

⁵ For a recent description of the main features of the German R&D funding system, see Aschhoff, 2009.

⁶ Why credit financing of R&D projects may be problematic (beyond the reasons already given in this paper) has been summarized in a paper by Himmelberg and Petersen, 1994. They argue for example that credit constraints may be more severe for innovation projects compared to other projects, due to the specific characteristics of R&D activities.

may still opt for relationship lending. The relation specificity can provide them with access to private data about the financed firm which can lead to a quasi monopolistic banking position and superior benefits from future business with the particular client (Boot and Thakor, 2000). In conclusion, the increased resource availabilities in larger banks can be expected to make them more likely to provide relationship loans for private R&D investments. We propose:

Hypothesis 1: Firm investment in R&D increases with the size of the corporate banking activities of their main bank.

The value of the knowledge resulting from an R&D project can often times only be judged by external parties after it is codified or visible, e.g. in a patent or a final product (Levitas and McFadyen, 2009). However, certain individuals have already information about the value of the knowledge before it reaches the explicit stage. Nonaka, 1994 provides a model for knowledge creating processes within a firm. The knowledge production starts at the individual level with a core group of scientist or engineers extending their individual knowledge base. This knowledge is often times tacit in nature. Ahuja et al., 2005 demonstrate that managers can exploit their inside information on the value of an innovation before it is patented. However, access to this information requires often times close geographical proximity. Knowledge flows have been found to be narrowly confined to certain regions (e.g. Audretsch and Feldman, 1996). Geographical distance in this context is typically perceived as a proxy variable for social ties that facilitate knowledge exchanges. These can be based on social capital that arises from shared educational or professional careers which increase the likelihood of individuals to communicate and exchange valuable information (Adler and Kwon, 2002; Agrawal et al., 2006). Similarly, finance literature has identified these mechanisms for the geographical specialization of financing that helps overcoming or exploiting information asymmetries. Coval and Moskowitz, 1999 find for the United States that investors prefer investments in firms that are closely located to their headquarters especially if the quality of these investments is difficult to assess (e.g. small firms). Grinblatt and Keloharju, 2001 find a similar home regional bias within Finland. We therefore conclude that specialized main banks in geographical proximity to a firm have a more comprehensive access to relevant information about a firm and its R&D activities and can therefore be considered to be more likely to provide lending. We hypothesize:

Hypothesis 2: Firm investment in R&D increases with the degree of spatial specialization of the corporate banking activities of their main bank.

Moreover, technological information especially in its early stages is often times complex, i.e. requires complementary knowledge from other domains to judge its full potential (e.g. Rivkin, 2000). Knowledge flows have been found to be dyadic in nature. This requires that both partners, in our case the firm and its main bank, are willing and able to exchange knowledge (Szulanski, 1996; 2000). The ability to absorb and evaluate technological knowledge is typically related to an organizations prior experience with particular innovation activities (Cohen and Levinthal, 1989). In that sense, banks operating with multiple clients in a particular sector can be expected to have prior experience with certain technologies and trends for the future. These may not just arise from past experiences but current lending engagements in a sector. Information externalities can help banks to reduce information

asymmetries within a certain sector (Stiglitz, 2002). Specialized banks can aggregate information from their loan portfolio which allows them to predict technological trends and competitive interactions in a sector more accurately (Boot and Thakor, 2000). In a typical loan application process a bank will benchmark the information of a prospective borrower against key figures from its other clients from the same sector. This comparison is often times based on information stemming from other lending contracts which is not publicly available. A strong engagement in a particular sector provides the bank therefore with information advantages compared to less specialized competitors. This advantage should allow them to overcome information asymmetries. We suggest:

Hypothesis 3: Firm investment in R&D increases with the degree of sector specialization of the corporate banking activities of their main bank.

Banks differ not just along their geographical and industry specialization. Certain banks have a political mandate for fostering growth within a certain region (e.g. savings banks) or for particular groups (e.g. coop banks). Especially the former type of banks has often times direct government ownership at the federal, state or municipality level. Porta et al., 2002 provide an overview on government banks and discuss their positive as well as negative effects on private firms. Financing private R&D can be seen as a primary driver of growth. This should provide firms with easier access to loans for their R&D projects. Then again, negative allocation effects because of political influence and a focus on large firms and economically depressed regions has been (Sapienza, 2004). Haselmann et al., 2009 find a negative relationship with investments in private innovation in Germany. We derive:

Hypothesis 4: Firm investment in R&D decreases if their main bank is a savings or cooperate bank.

4 Data, Variables and Methods

Databases and sample

For testing our hypotheses we use data from several waves of the German innovation survey called the “Mannheim Innovation Panel” (MIP). The survey is conducted annually by the Centre for European Economic Research (ZEW Mannheim) on behalf of the German Federal Ministry of Education and Research. For our study we use the waves 2003 to 2007 and analyse more than 4,750 firms with five or more employees in Germany. More than 3,090 firms we observe twice or more often. 118 firms are observed in all five years. The reporting period of each survey wave covers the previous three years, e.g. the 2005 wave collects information on innovation activities during the three years 2002, 2003 and 2004. The survey provides data on the innovation activities of firms from manufacturing as well as service sectors and follows the OECD’s Oslo Innovation Manual on measuring innovation inputs, outputs and processes (OECD, 2005). Decision makers on R&D or innovation managers are asked directly if and how their firms are able to generate innovative products, services and/or

processes. This enables constructing direct measures for innovation processes and outputs which can complement traditional measures of innovation activity such as patents. The survey sample is stratified by region (East and West Germany), firm size as well as industry and therefore representative for Germany as a whole. This feature provides a unique opportunity for the analysis of our research question as regional and industry differences can be explored. The MIP is the German contribution to the European Community Innovation Survey (CIS) coordinated by Eurostat and conducted in every EU member country and adheres closely to the CIS methodology and questionnaire. The CIS surveys are subject to extensive pre-testing and piloting in various countries, industries and firms with regard to interpretability, reliability and validity (Laursen and Salter, 2006). This multinational application of CIS surveys adds extra layers of quality management and assurance. It is therefore not surprising that CIS data have been the basis for several recent publications in highly ranked management journals (e.g. Laursen and Salter, 2006; Leiponen and Helfat, 2010).

The core database is enriched by information concerning a banks' credit portfolio gained by the Mannheimer Enterprise Panel (MUP). The MUP is a firm-level database collected by Creditreform, the largest credit rating agency in Germany. Since 1999, ZEW receives twice a year a full copy of Creditreform's data-warehouse of firm level data and constructs the panel. The MUP is based on information that allows assessing a firm's credit worthiness. It also covers firm's bank relations. Since the database has nearly a full coverage of firms located in Germany, information on bank relations are used to reconstructed the credit portfolio in corporate finance for each bank for the 2002 to 2006 period. For this analysis the banks credit portfolio is reconstructed in terms of sector and spatial specialization or diversification. Firms are assigned to a bank based on their main bank branch.

Variable Description⁷

Independent Variable

Innovative firms are defined as those that invest in R&D. We measure the firm's resource allocation using R&D expenditures per sales. Both sales and R&D expenditures are collected in the MIP surveys. The variable takes on the value zero for firms that have no R&D expenditures in a particular year. For firms with R&D expenditure, the value of the variable varies between 0.01% and 100%.

Bank related variables

The structure of the German banking system is often described as the "Three Pillar System" (see e.g. Krahn and Schmidt, 2004; Engerer and Schrooten, 2004) and consists of public owned savings banks (in German: "Sparkassen"), cooperative and private banks. All these banks are active as universal banks. We split large private banks⁸ into regional divisions based on the regional differentiation of the German Banking Code (2 digits) in order to make them

⁷ Tables with addition information on the construction of our variables can be found in the Appendix (Table 3 and 4)

⁸ The Deutsche Bank, Dresdner Bank, Commerzbank and Hypo-Vereinsbank (now Unicredito) are recognized as large banks.

more comparable to decentralized saving banks and cooperative banks. In the 2000-2005 period private banks (real estate credit institutions and commercial banks) together with Landesbanken⁹ had a market share of 64 % in corporate finance (Bundesverband Deutscher Banken e.V., 2009). In our sample this group covers 52 % of all observations. For almost a third (31 %) of the sample firms' main banking services are provided by savings banks and for 17 % by cooperative unions. The variable *Savings and Cooperative Banks* is one if the firm's main bank belongs to that particular group. The variable *Bank Size* is calculated for each bank, as the sum of all employees of the firms that have this particular bank as their main bank. *Bank Size Industry* covers the size of a bank related to a certain industry. It is calculated as the sum of employee weighted firms that share the same industry and main bank as the particular firm at hand.

Banks can build up specific spatial or industry knowledge. Specialized banks might be better able to assess projects and reduce asymmetric information. However, specialized banks may be more prone to idiosyncratic risk. Based on the bank's credit portfolio we are able to identify the industry¹⁰ and spatial concentration of banks. *BankIndShare* is the relation between *Bank Size Industry* and the overall, employee weighted, number of firms with the same main bank (*Bank Size*). Bank concentration or diversification over industry is measured using the Herfindahl-Hirschman-Index. *BankIndHHI* is calculated by the squared sum of *BankIndShare*. The Variable *Sector Specialization* is derived as an interaction between the variable *BankIndShare* and *BankIndHHI*. The value of this variable increases, the more the bank is involved in the industry of the firm and the less the bank diversifies their portfolio over industries. Information concerning a bank's spatial diversification is measured similarly (*BankRegionShare*, *BankRegionHHI* and *Spatial Specialization*) Spatial concentration is measured on the level of planning regions¹¹ In order to control for non-linear functional forms we use also squared values of the variables *Sector Specialization* and *Spatial Specialization*.

Firm related control variables

To account for differences in firm's past R&D activities we calculate the patent stock for each firm through the depreciated sum of all patents it had filed in the European Patent Office database from 1978 until 2005 and divide it by the total number of employees. We follow existing literature (e.g. Aerts and Schmidt, 2008; Griliches and Mairesse, 1984) and use an annual depreciation rate of 15%. Furthermore we include variables that proxy for the access to alternative sources of financing for R&D and other projects. We include the legal form (limited liability corp. or stock company) of the firm, whether it received any public R&D funding, and its "credit rating". Two variables, which can be considered proxies the level of cash flow of a firm, are also included in our analysis. These are the profit to sales ratio and the share of export to total sales. Firms may also be able to access financial means for R&D projects from related firms, if they belong to a group of firms. We therefore include a dummy

⁹ Also Landesbanken are owned jointly by states and Sparkassen these banks are grouped to private banks because of similar lending strategies.

¹⁰ For industry classification NACE Rev 1.1 (2 digits) is used throughout the analysis either for firms or bank portfolios.

¹¹ There exists 97 planning regions that are aggregates from NUTS 3 regions. Those planning regions must not be restricted to states (NUTS 2).

variable, which is one, if the firm is a subsidiary of a group. In order to control for other firm characteristics we make use of the number of employees, the firm age, the industry group it belongs to, and its location in East or West Germany.

Empirical Model

We assume that a firm (i) can choose to invest in R&D and if it does, it can choose the degree of its R&D investment. This choice can be modelled as follows:

$$Y = \alpha + \beta * B + \gamma * X + \epsilon$$

with Y measuring the R&D expenditure per sales. The decision of the extent of R&D investment is likely to depend on the bank's possibility to overcome problems of asymmetric information. In order to model the bank's strategy and firm's innovation investment we vary bank related variables in the vector B. The vector X covers the firm characteristics, such as industry, firm size and age.

Due to the left- and right-censored nature of the dependent variable we estimate censored panel regression models. In particular we estimate random effects Tobit models that require the assumption of no correlation between the set of regressors and a firm-specific time-constant effect (see Wooldridge, 2002).¹²

5 Results

The results of the random effects Tobit estimations are presented in Table 1 below. The first three columns refer to models in which we control for the total size of the bank whereas columns (4) to (6) include only a dummy for the total exposure of the bank in a specific sector. The basic models (columns 1 and 4) are extended in columns (2) and (3) and (5) and (6) respectively with measures of the sectoral and spatial specialization of the banks and therefore allows for testing hypotheses 2 and 3. In order to test hypothesis 4 each model also includes a variable indicating whether the bank is a public savings or cooperative bank or not.

The results provide mixed evidence on our hypotheses. Only hypothesis four is confirmed by all our estimations. Firms whose main bank is a public savings and cooperative banks have lower R&D intensities than firms mainly dealing with public banks. This is in line with the findings of Haselmann et al., 2009.

¹² Cameron and Trivedi, 2005 noted that the maximum likelihood estimator of a fixed effects Tobit model is not consistent.

Table 1 Results of Tobit model (coefficients) – Dep. Variable: Share of R&D expenditure in total sales

VARIABLES	I Total Bank Size			II Bank Size in the Industry		
	(1) Basic Model	(2) Special- ization	(3) Special- ization Sq.	(4) Basic Model	(5) Special- ization.	(6) Special- ization Sq.
Savings and Cooperative Banks	-0.013*** (0.005)	-0.014** (0.006)	-0.012* (0.006)	-0.024*** (0.005)	-0.023*** (0.006)	-0.019*** (0.006)
Bank Size, ln	0.002 (0.002)	0.002 (0.002)	0.001 (0.002)			
Bank Size Ind, ln				-0.007*** (0.001)	-0.007*** (0.001)	-0.007*** (0.001)
Sector Specialization		-0.083 (0.095)	-0.465*** (0.168)		-0.023 (0.089)	-0.235 (0.170)
Sector Specialization sq.			0.672*** (0.237)			0.369 (0.247)
Spatial Specialization		0.001 (0.007)	0.050* (0.027)		-0.003 (0.007)	0.049* (0.027)
Spatial Specialization sq.			-0.053* (0.028)			-0.057** (0.028)
Profit to sales ratio	-0.003* (0.002)	-0.003* (0.002)	-0.003* (0.002)	-0.003* (0.002)	-0.003* (0.002)	-0.003* (0.002)
Patent stock per employee	1.547*** (0.271)	1.547*** (0.271)	1.533*** (0.271)	1.545*** (0.271)	1.541*** (0.271)	1.529*** (0.271)
Share of export in total sales	0.113*** (0.009)	0.112*** (0.009)	0.112*** (0.009)	0.112*** (0.009)	0.112*** (0.009)	0.112*** (0.009)
Limited liability corp. or stock company	0.035*** (0.008)	0.035*** (0.008)	0.034*** (0.008)	0.035*** (0.008)	0.035*** (0.008)	0.035*** (0.008)
Rating	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)	0.001 (0.002)
Recipient of public R&D funding	0.085*** (0.004)	0.085*** (0.004)	0.085*** (0.004)	0.085*** (0.004)	0.085*** (0.004)	0.085*** (0.004)
Number of employees, ln	-0.000 (0.002)	0.000 (0.002)	0.000 (0.002)	0.001 (0.002)	0.001 (0.002)	0.002 (0.002)
Firm age, ln	-0.013*** (0.003)	-0.013*** (0.003)	-0.013*** (0.003)	-0.012*** (0.003)	-0.012*** (0.003)	-0.013*** (0.003)
Subsidiary of group, dummy	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.004)

(continued on next page)

Table 2 Results of Tobit model (coefficients) - continued

VARIABLES	I Total Bank Size			II Bank Size in the Industry		
	(1) Basic Model	(2) Special- ization	(3) Special- ization Sq.	(4) Basic Model	(5) Special- ization.	(6) Special- ization Sq.
East Germany, dummy	0.007 (0.005)	0.007 (0.005)	0.007 (0.005)	0.005 (0.005)	0.005 (0.005)	0.005 (0.005)
Medium-tech manufacturing	0.038*** (0.006)	0.038*** (0.006)	0.038*** (0.006)	0.039*** (0.006)	0.039*** (0.006)	0.039*** (0.006)
High-tech manufacturing	0.086*** (0.008)	0.086*** (0.008)	0.086*** (0.008)	0.086*** (0.008)	0.086*** (0.008)	0.085*** (0.008)
Low knowledge-intensive services	-0.036*** (0.008)	-0.036*** (0.008)	-0.036*** (0.008)	-0.028*** (0.008)	-0.028*** (0.008)	-0.029*** (0.008)
Knowledge-intensive services	0.056*** (0.006)	0.057*** (0.007)	0.059*** (0.007)	0.067*** (0.007)	0.068*** (0.007)	0.068*** (0.007)
Constant	-0.133*** (0.024)	-0.130*** (0.024)	-0.129*** (0.025)	-0.069*** (0.015)	-0.068*** (0.015)	-0.076*** (0.016)
Constant Sigma U	0.107*** (0.002)	0.107*** (0.002)	0.106*** (0.002)	0.106*** (0.002)	0.106*** (0.002)	0.106*** (0.002)
Constant Sigma E	0.076*** (0.001)	0.076*** (0.001)	0.076*** (0.001)	0.076*** (0.001)	0.076*** (0.001)	0.076*** (0.001)
Observations	7,849	7,849	7,849	7,849	7,849	7,849
Number of id	4,792	4,792	4,792	4,792	4,792	4,792
chi2	1,262	1,263	1,273	1,297	1,297	1,302
log likelihood	787.0	787.4	792.8	803.5	803.6	806.6

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Own calculations.

Hypothesis one is rejected by our empirical results. The fact that a firm's bank is large in terms of corporate banking activities does not significantly influence its R&D intensity. What is more, the size of the corporate banking activity in the firm's industry even reduces the R&D intensity of the firm in question. A finding that is underscored by the fact the sector specialization variable, which measures the degree of specialization rather than the scale of the activities, is negative (even though insignificant) in equation (2) and (5), contrary to our expectations formulated in hypothesis 3.

Taking these findings together it looks like more sectoral concentration on the side of the banks leads to less R&D (in relation to their sales) by the firms they do business with. One reason may be that the banks are able to select only the best R&D projects, because of their experience in the industry, and therefore do not provide funding for more risky and bad

projects. This would result in a reduction of R&D intensities, compared to a situation where banks would also finance the latter projects. Risk considerations may also play another role in explaining our findings. Bank may wish to diversify their credit and loan portfolios, both in terms of industry coverage and with respect to R&D projects. As a result they may not be willing to take on high levels of risk in the form of R&D projects if they are already little diversified in terms of industry coverage. The latter argument about risk could potentially also explain our findings in equation (3), that the relationship between sector specialization is non-linear, to be more precise u-shaped. What this indicates is that firms are more R&D intensive if they do their banking with less specialized banks. However, the u-shape also indicates that the R&D intensities are higher for firms whose main bank is highly concentrated.

Concerning the u-shaped relationship between a firm's R&D investment and the industry specialization, we suspect that highly specialized banks benefit from unique information advantages due to reduced levels of information asymmetry when evaluating an R&D project. Banks with low degrees of specialization in the focal firm's industry, though, may be more willing to finance R&D investment because it diversifies the risk of their overall loan portfolio. The combination of both forces results in an overall u-shaped relationship. This certainly needs further investigation in future studies, however. In summary hypothesis 3 can by and large be rejected, even though there is some evidence that very high levels of sectoral specialization by banks has a positive impact on R&D intensity levels. For spatial specialization we also find a non-linear relationship. The relationship between this variable and the R&D intensity is inverse-u-shaped. We suppose that this effect is due to the fact that banks require a balanced pool of information about potential returns of R&D projects. A too narrowly defined focus may leave them overly cautious while a too broad focus will not allow for the depth of information that is required. However, the turning-point for the inverse-U can be calculated to lie at 0.001, i.e. only the downward-sloping part of the inverse-U is relevant. This indicates that highly concentrated banks seem to be less willing to finance R&D projects than other banks. As a consequence hypothesis two has therefore to be rejected. This is a surprising result, as the existing literature on bank-firm relationships finds strong evidence in favor of a positive effect of geographic proximity on access to finance (see section 3 above). Our results indicate that factors that mitigates the advantages that stem from geographical proximity (like easy access to soft information) may exist for R&D projects. Again, the risk argument presented above could be an avenue for future research on this issue.

The control variables mainly exhibit signs and significance levels in line with our expectations. Public R&D funding and access to capital markets (limited liability or stock company variable) e.g. have a positive and significant relationship with the R&D intensity. As expected, firms in high-tech and high-knowledge intensive industries exhibit higher levels of R&D intensity than firms in other industries. The rating variable has no significant influence which is surprising and may indicate that the main information of the rating is already controlled for by over variables included in the analysis.

6 Conclusions and Future Research

The primary goal of this analysis was to analyze the impact of banks on R&D intensities of firms. We paid particular attention to the heterogeneity of banks with respect to spatial and sectoral specialization. Contrary to our expectations we find that firms that do business with more specialized banks, tend to have significantly lower R&D intensities than other banks. We argue that this may be due to risk considerations on the side of banks, i.e. more concentrated banks seem to be less willing to take on additional risk in the form of R&D projects.

Our arguments in the theoretical section of this paper made use of the literature on asymmetric information. Our main points were that a reduction of information asymmetries will increase the probability that a firm gets funding for its R&D projects and that the level of information asymmetries between specialized banks is low. The estimation results, however, do not confirm this hypothesis. It looks like a reduction in information asymmetries does have a negative effect on R&D intensities. An explanation for this finding is that banks that are better able to evaluate R&D project select only the least risky and most promising projects, and do not provide funding for very risky projects. Under the assumption that the firm is not able to get funding for the risky projects elsewhere (maybe due to a negative signal sent by the rejection from the bank), its R&D intensity would be lower. This would constitute a negative effect of a reduction information asymmetries. This may be an interesting topic for future empirical as well as theoretical research, while bank may profit from a reduction in information asymmetries, firms may suffer. Unfortunately we are not able to categorize the R&D project proposals the firms sent to the banks according to their risk levels. As a result we cannot investigate whether the more specialized banks used their specialization advantages in order to identify and finance only the good (less risky) projects.

Our analysis provides important implications for both management and policy makers. First, we provide evidence for the importance of the choice of a particular main bank for a firm. We develop a profile of banks with regard to how likely they are to correctly assess a firm's investment into new products and services. Managers can exploit this heterogeneity among banks and choose a partner bank which supports its investments into future competitive assets through R&D. Taking our preliminary results at face value, it looks like firms looking for R&D project funding from banks should try to find banks with little local or industry specialization in order to get a loan or credit for their R&D activities. Secondly, the banking industry is heavily influenced by government policy. These may take the form of regulatory intervention or even direct ownership (e.g. Porta et al., 2002). Policy initiatives with the particular focus of fostering private investment in innovation activities can include elements that make it easier for firms to obtain bank loans. Our finding can provide guidance for policy programs with this particular intent and describe a favorable bank profile.

Future research should try to investigate the relationship between information asymmetries and R&D finance in more detail. The link between the risk levels of a banks portfolio and its probability to finance R&D also seems a promising future research topic.

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APPENDIX

Table 3 Construction of industry variables

Industry	NACE Code	Industry Group
Mining and quarrying	10 – 14	Other manufacturing
Food and tobacco	15 – 16	Other manufacturing
Textiles and leather	17 – 19	Other manufacturing
Wood / paper / publishing	20 – 22	Other manufacturing
Chemicals / petroleum	23 – 24	Medium high-tech manufacturing
Plastic / rubber	25	Other manufacturing
Glass / ceramics	26	Other manufacturing
Metal	27 – 28	Other manufacturing
Manufacture of machinery and equipment	29	Medium tech manufacturing
Manufacture of electrical machinery	30 – 32	High-tech manufacturing
Medical, precision and optical instruments	33	High-tech manufacturing
Manufacture of motor vehicles	34 – 35	Medium tech manufacturing
Manufacture of furniture, jewellery, sports equipment and toys	36 – 37	Other manufacturing
Electricity, gas and water supply	40 – 41	Other manufacturing
Construction	45	Other manufacturing
Retail and motor trade	50, 52	Low knowledge-intensive services
Wholesale trade	51	Low knowledge-intensive services
Transportation and communication	60 – 63, 64.1	Low knowledge-intensive services
Financial intermediation	65 – 67	Knowledge-intensive services
Real estate activities and renting	70 – 71	Distributive services
ICT services	72, 64.3	Knowledge-intensive services
Technical services	73, 74.2, 74.3	Knowledge-intensive services
Consulting	74.1, 74.4	Knowledge-intensive services
Other business-oriented services	74.5 – 74.8, 90	Low knowledge-intensive services

Table 4 Variable Description

Variable Name	Variable Construction	Further Explanations
Savings and Cooperative Banks	= 1 if the main bank is Savings Bank or Cooperative Bank = $\sum_i n_{ij}$	Landesbanken are grouped together with private banks.
Bank size		Bank size in terms of the sum of (employee weighted) firms with the same main bank.
BankIndShare	= $n_{ij} / \sum_j n_{ij}$ = $\sum_i (n_{ij} / \sum_j n_{ij})^2$	Share of a bank portfolio in a given industry. Herfindhal-Hirschman-Index of the industry concentration of a given bank portfolio.
BankIndHHI	= $(n_{ij} / \sum_j n_{ij}) * \sum_i (n_{ij} / \sum_j n_{ij})^2$	Interaction between the share of a bank portfolio in a given industry and the bank's HHI of industry concentration.
Sector Specialization	= $n_{rj} / \sum_r n_{rj}$	Share of a bank portfolio in a given planning region.
BankRegionShare	= $\sum_r (n_{rj} / \sum_r n_{rj})^2$	Herfindhal-Hirschman-Index of the spatial concentration of a given bank portfolio.
BankRegionHHI	= $(n_{rj} / \sum_r n_{rj}) * \sum_r (n_{rj} / \sum_r n_{rj})^2$	Interaction between the share of bank portfolio in a given planning region and the bank's HHI of spatial concentration.
Spatial Specialization		
Profit to sales ratio	= Profit / sales	
Patent stock per Employee	= patent / # of employees	
Number of employees, ln	= ln (employees)	
Firm age, ln	= ln (firm age)	
Public R&D funding, dummy	= 1 if firm received public funding = $(\text{rating} - \text{mean}(\text{rating})) / \text{sd}(\text{rating})$; lagged by one year; rating provided by Creditreform	Variable is lagged by one year. Rating information was provided by Creditreform.
Rating		
Limited liability corporation or stock company, dummy	= 1 if the firm is either a limited liability corporation (GmbH, GmbH & Co. KG) or a joint stock company (AG)	Either a limited liability corporation (GmbH, GmbH & Co. KG) or a joint stock company (AG).
Share of export in total sales	= export sales / sales; lagged by one period	
Subsidiary of group	= 1 if the firm is a subsidiary company	
East Germany	= 1 if the firm is located in East Germany	
Medium-tech manufacturing	see Table 3	
High-tech manufacturing	see Table 3	
Low knowledge-intens. Services	see Table 3	
Knowledge-intens. Services	see Table 3	
n	= # of employee weighted firms	
i	= Index for Industry	
j	= Index for Bank	
r	= Index for Region	

Table 5 Descriptive Statistics (Means, Standard Deviations)

Variable	Scale	Obs	Mean	Std. Dev.
Savings and Cooperative Banks	dummy	7,849	0.484	0.500
Bank Size	continuous	7,849	66071	92262
BankIndShare	share	7,849	0.059	0.076
BankRegionShare	share	7,849	0.657	0.351
Sector Specialization	continuous	7,849	0.007	0.023
Spatial Specialization	continuous	7,849	0.523	0.365
Profit to sales ratio	share	7,849	-0.033	0.987
Patent stock per employee	continuous	7,849	0.001	0.007
Number of employees	continuous	7,849	160.	370
Firm age	continuous	7,849	17.2	14.6
Recipient of public R&D funding	dummy	7,849	0.156	0.363
Rating	continuous	7,849	0.009	0.862
Limited liability corporation or stock company	dummy	7,849	0.901	0.299
Share of export in total sales	share	7,849	0.141	0.232
Subsidiary of group	dummy	7,849	0.404	0.491
East Germany	dummy	7,849	0.365	0.481
Medium-tech manufacturing	dummy	7,849	0.289	0.453
High-tech manufacturing	dummy	7,849	0.082	0.274
Low knowledge-intens. services	dummy	7,849	0.143	0.350
Knowledge-intens. services	dummy	7,849	0.287	0.452

Table 6 Panel Structure

Year variables refer to	Number of Obs.	Percent of total
2002	1,548	19,72 %
2003	699	8,91 %
2004	1,967	25,06 %
2005	1,370	17,45 %
2006	2,265	28,86 %
Total	7.849	100 %