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The Importance of Equity Finance for R&D Activity – Are There Differences Between Young and Old Companies?

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Non-technical Summary

The innovative activity of companies is a driving force for economic growth. New developments benefit consumers by offering a greater choice of products and services. Although large companies spend a high share of the total R&D expenditure of the private sector, small and medium-sized companies (SMEs) are also important players in the innovation process. In 2004, companies with less then 500 employees contributed to 12.5% to the R&D expenditures of the German private sector.

In this paper we analyze whether the equity capital available to SMEs affects their R&D activity using a representative survey of German companies. Equity is important for the R&D activity, since bank loans are difficult to obtain for R&D projects. Banks prefer to lend to safer projects that are easier to evaluate and provide more collateral. Young companies have specific problems with bank loans due to their higher default risk and since they still need to establish a relationship with the bank. We test the hypothesis that companies with a higher equity ratio will engage more in R&D activities, measured alternatively as the probability of pursuing R&D and as the R&D intensity (ratio of R&D expenditures to sales). The hypothesis is tested separately for young and old companies.

Using banking competition at the district level as instrument to control for reverse causality, we find that a higher equity ratio is conducive to more R&D for young but not for old companies. Whereas old companies have had time to build up equity via retained profits, young companies have to rely on the original investment of the owners. In addition, should extra financing be required while the R&D project is executed, older companies can rely more on bank loans whereas young companies need to provide a financial cushion for bad times themselves.

The positive influence of equity financing is only found for R&D intensity but not for the decision whether to perform R&D. This suggests that equity is only important for higher levels of R&D intensity, for example for young high-tech firms. These companies therefore depend on a functioning market for external equity, if the personal funds of the original owners are not sufficient to cover the financing needs. If R&D is only a minor part in the overall activities, young companies do not have a special requirement in terms of equity to finance their R&D. It can be that for these firms the level of overall risk is low enough for banks to be more willing to extend loans.

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- FORTHCOMING: SMALL BUSINESS ECONOMICS -

Abstract

This paper analyzes the importance of equity finance for the R&D activity of small and medium-sized enterprises. We use information on almost 6000 German SMEs from a company survey. Using the intensity of banking competition at the district level as an instrument to control for endogeneity, we find that a higher equity ratio is conducive to a higher R&D intensity. Owners may only start R&D activities if they have the financial resources to sustain them until successful completion. We find a larger influence of the equity ratio for young companies. Equity may be more important for young companies which have to rely on the original equity investment of their owners since they have not yet accumulated retained earnings and can rely less on bank financing.

JEL classification: G 32, O 32

Keywords: R&D activity, equity finance, small and medium-sized enterprises

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1 Introduction

The innovative activity of companies is a driving force for economic growth. Consumers benefit from a greater choice of products and services, whereas companies benefit from the creation of additional markets and earning opportunities. At the macroeconomic level, innovations speed up structural adjustment to engender new viable sectors and play a vital part for the creation of new jobs (Peters (2004)). Although large companies spend a high share of the total R&D expenditure of the private sector, small and medium-sized companies (SMEs) are also important players in the innovation process. In 2004, companies with less than 500 employees contributed 12.5% to the R&D expenditures of the German private sector (Stifterverband (2005)). On the one hand, small companies face disadvantages because they cannot exploit scale economies and are restricted in the types of financing they can raise for their R&D activities. On the other hand, some characteristics of SMEs even facilitate the implementation of R&D projects (Acs and Audretsch (1990)). Managers may know more about the technology, there may be an entrepreneurial spirit more favourable to risk taking, and researchers may encounter fewer bureaucratic hurdles (Scherer (1991); Link and Bozeman (1991)).

The literature on R&D activity has originally mainly concentrated on the influence of company size, technological opportunity and appropriability (Cohen and Levin (1989)). More recently, the influence of the financial structure of the company has also been of interest. Whereas some authors considered the influence of cash-flows (see, for example, Himmelberg and Petersen (1994)), we focus on the influence of equity financing.

The purpose of this paper is to provide an analysis of whether the equity capital available to companies affects their R&D activity using a representative survey of German companies from KfW Bankengruppe (formerly Kreditanstalt für Wiederaufbau). We test the hypothesis that companies with a higher equity ratio will engage more in R&D activities, measured alternatively as the probability of pursuing R&D and as the R&D intensity (ratio of R&D expenditures to sales).

We focus on unlisted, small and medium-sized companies. In contrast to listed companies, they depend for their equity financing strongly on the personal funds of a limited number of owners. Furthermore, we differentiate between young and old companies. The R&D activity of young companies is more likely to be constrained by the availability of equity capital, since young companies have not yet had the opportunity to increase their equity base by accumulated earnings. We look at R&D expenditures as proxy for innovation since R&D activities have typically a higher risk than other innovative activities, such as spending money for licenses or for machines needed for new products.

Our results show that a higher equity ratio is conducive to a higher R&D intensity. Owners may only start R&D activities if they have the financial resources to sustain them until successful completion. We find a larger effect for young companies. Equity may be more important for young companies which have to rely on the original equity investment of their owners since they have not yet accumulated retained earnings and can rely less on bank financing. We do not find a positive influence of the equity ratio on the decision whether to perform R&D. Equity is therefore less important for companies for which R&D is only a small part of the overall activities.

We improve on the existing literature in several ways. First, most of the literature investigating how the financial side of companies influences their R&D activity is concerned with sensitivities of cash-flow and R&D. However, cash-flow varies from year to year whereas R&D often has a continuous component since it exhibits high adjustment costs. Furthermore, a higher sensitivity of R&D to cash-flow may effectively indicate that the company responds faster to changes in demand conditions (Hall (2005)). In contrast, the equity ratio as a stock variable is an indicator of the resources that the company has available. Especially for SMEs, this more fundamental characteristic of the company may be more relevant for the R&D decision. The cash-flow measure is possibly problematic for young companies, which are still in the process of building up a customer base.

Second, we take the direction of causality explicitly into consideration. On the one hand, the availability of equity can influence the R&D activity, since owners will only start R&D projects if their capital base is sufficient to sustain projects until returns materialize. R&D projects often have no early cash flow to secure interest payments on loans and owners may be unwilling to engage in R&D if it endangers the survival of the company. On the other hand, companies with R&D activity may find debt financing especially expensive or may not have access to this type of financing at all. In addition, if innovative companies benefit from successful R&D projects via higher profits, they can increase their equity base through retained earnings. In order to identify the first direction of causality, we use two alternative instruments for the equity ratio. The first instrument is competition in the banking sector at the district level; the second is a rating of the financial standing of the company, a part of the company's credit rating.

Finally, we provide evidence for a bank-based system. Prior research found less severe financial constraints for innovative SMEs in bank-based systems (Hall (2005)). Our data set covers the whole spectrum of SMEs with respect to age, size and industry and covers companies with as well as without R&D activity.

This paper is organized as follows. Section 2 explains the theoretical background to financing decisions and R&D activity. Section 3 summarizes the existing literature. Section 4 describes the data set. Section 5 covers descriptive statistics. Section 6 presents the empirical results. Section 7 concludes.

2 Theoretical Background

R&D projects have special characteristics that make external financing difficult. First, returns of R&D projects are highly uncertain. Often there is a high probability of failure combined with the possibility of high returns if successful. Second, the quality of R&D projects is difficult to evaluate. Not only is technical knowledge necessary, but owners also want to keep details of their R&D activity secret. This results in severe problems of asymmetric information in the form of adverse selection and moral hazard, which can affect the willingness of investors to provide both equity and debt capital ((Hall (2005) and Stiglitz and Weiss (1981)). Because a high R&D intensity is often an indicator for complex or radical innovations which are largely untested in the market, both uncertainty and asymmetric information increase with R&D intensity.

Young companies may face specific challenges when conducting R&D. Lucas (1993) and Irwin and Klenow (1994) point out that learning by doing leads to cost advantages for firms with more market and R&D experience. Conducting R&D may therefore be more expensive for younger firms than for older ones. Furthermore, R&D projects are often indivisible (Cohen and Klepper (1996)) and young companies may have a lower amount of output over which to spread the costs.

Companies can choose between three broad types of financing: internal financing (equity from existing owners and retained earnings), external debt and external equity. Evidence from different countries shows that SMEs rely mostly on internal financing (Giudici and Paleari (2000) and Manigart and Struyf (1997)). If SMEs seek outside financing, then bank loans are the preferred type (Hughes (1997)). In contrast, accessing external equity is a rare event. Ou and Haynes (2006) find for SMEs in the US that less than 1% of the surveyed companies used this financing type.

The specific characteristics of R&D projects described above make debt financing in particular difficult (Himmelberg and Petersen (1994)). Due to fixed interest payments banks do not participate in the high returns of successful outcomes. They are therefore more concerned with the probability of failure when calculating the price for the loan, which can lead to high interest rates or to the decision not to lend at all (Stiglitz (1985)). Furthermore, R&D projects often do not involve assets that can be used as collateral. Wages of scientists and engineers account for a high share of R&D expenditures and if tangible assets are bought, they have often a low resale value because they are company specific. R&D activity therefore provides little inside collateral that could be offered to banks to make lending less risky. As shown by Bester (1985), collateral is also important because it can be used as a screening device to avoid rationing in credit markets.[1]

Empirical evidence shows that innovators have a significantly lower probability of being successful with long-term loan applications (Freel (1999)). The probability of being successful with loan applications decreases as the R&D intensity of the companies increases (Freel (2007)). However, the author finds tentative evidence that a limited degree of innovative activity may be better than a lack thereof, since it may signal a higher viability of the company. Schäfer et al. (2004) investigate the choice between debt and equity for young innovative SMEs in Germany. They find that banks limit their risk by concentrating on firms with a high equity ratio, high price-cost-margin and a smaller deal size.

Young companies have age-specific problems with access to bank loans. Banks use relationship lending to alleviate problems of asymmetric information when lending to small companies (see, for example, Petersen and Rajan (1994) and Berger and Udell (1995)). Banks collect information about the companies over time, which allows them to make well-

[1]Collateral is an important instrument used by banks. In their sample of bank loans extended by five large German banks, Elsas and Krahnen (2002) find that 71% of the loans are collateralized and 31.5% of the total credit volume is covered by collateral. Lehmann et al. (2004) report average collateral coverage of 61% for Western Germany and 53% for Eastern Germany.

founded loan decisions. Since young companies start without such a track record, banks may be reluctant to offer them loans. Also, young companies generally have less collateral available to pledge to banks (Berger and Udell (1998)). This can be an especially severe problem for technology-based start ups with high R&D intensity and large financing requirements. The higher default risk of young companies is a further age specific impediment for bank loans. Fritsch et al. (2006) document the probabilities for going out of business for German companies, finding a decrease in the probability of exit with firm age. After ten years only 46 percent of the start-ups in manufacturing are still in business and about 37 percent of the start-ups in services. There are several possible reasons for the higher exit rates of young companies, among them inexperienced management, problems developing a customer base and problems establishing the product in the market.

Because of the above-mentioned problems of bank loans, external equity is considered as an important source of finance for innovative firms. Venture capital (VC) as "smart capital" – with the expertise in selecting the projects, qualified consultations and assistance – increases the prospects of success and consequently the expected project value. This characteristic combined with participation in the upside potential of projects makes VC more suitable for the financing of R&D than bank loans. However, the share of VC financing that is available for the seed phase is very limited. Venture capitalists are reluctant to finance technology based companies at a very early stage (Bottazzi and Da Rin (2002)). Murray and Lott (1995) find that UK venture capitalists set more rigorous criteria for technology projects than for non-technology projects. In addition, evidence from Scott (2000*a*) shows that owners are averse to losing control to venture capitalists. Even in countries with a well developed VC market, some owners will find the cost of using this financing type too high. External equity can also be raised by admitting additional owners to the company. Yet, this route of financing also means that existing owners will lose part of their control, which may deter owners from using this possibility (Cressy and Olofsson (1997) and Müller (forthcoming)).

How well is the German financial system adapted to the financing of young, high-technology companies? Throughout post-war history and, to a more limited extent, also up to now, the German financial system has been characterized by its strong focus on debt financing and bank intermediation. Audretsch and Eston (1997) find that the system is well suited to finance large and small companies in traditional sectors. However, it is less well suited to finance startups in newly emerging high-technology industries. In addition, the VC market in Germany is not well developed (Zimmermann and Karle (2005)). In the year 2005 only 1029 companies received venture capital financing (BVK (2006)), although there are approximately 36,000 SMEs performing continuous R&D in Germany (Rammer et al. (2006)).[2] Furthermore the early stage segment in the German VC market has been declining since the boom period at the end of the nineties. The share of the early stage segment in total fundraising decreased from 35 percent in 2000 to 13 percent in 2005 (BVK (2006)). This shows that even investors in the VC market hesitate to take the high risks of young innovative firms. Because funds have increasingly been pulled out of the early stage in Germany since 2001 and have been invested in the later stage, investments in the early stage segment in recent years were lower than at the end of the 1990s. So it is not surprising that VC investments in German high-tech startups are still scarce: Only 5.5% of all high-tech startups founded between 1996 and 2005 received venture capital (Niefert et al. (2006, p. 29)). In contrast to Germany, the US has a stock-market based financial system with a much more developed VC industry. Black and Gilson (1998) point to the importance of stock markets as exit opportunity for venture capitalists. The volume of VC investments as percentage of GDP is three times higher in the US than in Germany (Bottazzi and Da Rin (2002)).

From the above discussion of potential problems with external financing and of the characteristics of the German financial system it can be concluded that internal financing will play an important role in the financing of R&D activities of German companies. In fact, internal financing may be a restricting factor. This may be especially the case for young companies, since they have not yet accumulated retained earnings. Accordingly, the empirical analysis in this paper investigates whether firms with a high equity ratio carry out more R&D and whether the importance of the equity ratio is higher for younger firms.

[2] The number of R&D performing SMEs in Rammer et al. (2006) includes only companies with at least five employees and excludes the retail sector. The statistics of the German Private Equity and Venture Capital Association (BVK) are the most comprehensive information available. According to the BVK they cover 90% of the volume of the German VC market (Krahnen and Schmidt (2004)).

3 Related Literature

The analysis in this paper focuses on the influence of the financial structure on the R&D activity of companies. This direction of causality has so far found limited attention in the literature. Baldwin et al. (2002) use data for Canadian SMEs to investigate the relationship of R&D intensity and leverage in a system of equations but do not discuss identifying restrictions. For listed companies in the US, Singh and Faircloth (2005) document a negative influence of leverage on R&D intensity. The authors restrict their sample to companies with minimum positive R&D expenditure and do not use instruments to establish the direction of causality. Since the sample excludes companies without R&D and without continuous R&D activity, the analysis can not cover the decision to undertake R&D. For large German companies, Czarnitzki and Kraft (2004) identify a negative relationship between leverage and innovation output measured by patents. Bhagat and Welch (1995) compare the influence of leverage on R&D intensity across countries for listed companies using a VAR approach. For the US they find a positive effect, whereas it is negative for Japan. The authors conclude that US lenders may be less willing to finance R&D projects. Also using a VAR approach, Chiao (2002) finds a negative influence of debt on R&D intensity for listed US companies in science-based industries and a positive influence for companies in nonscience-based industries.

So far, the literature has mainly been concerned with the direction of causality from R&D activity to the capital structure. For a sample of SMEs from the UK, Jordan et al. (1998) find that companies with an innovation strategy have lower leverage and companies with a higher capital intensity have higher leverage. Both effects can be explained with the availability of collateral. Hyytinen and Pajarinen (2005) study the determinants of leverage for small, unlisted Finnish companies. The authors document especially low leverage for companies in the ICT sector with high R&D intensity. In contrast, Mac An Bhaird and Lucey (2006) find no relationship between R&D intensity and short- and long-term leverage for Irish SMEs. Some authors restrict their analysis to the influence of the asset structure. Chittenden et al. (1996) find a positive relationship between the share of fixed assets and leverage for unlisted UK companies. For Australian companies in the start-up phase, Cassar (2004) finds that the share of fixed assets has a positive relationship with long-term leverage and bank financing but a negative relationship with total leverage and outside financing.

The way R&D activity influences leverage has also been studied for large companies. Bah and Dumontier (2001) find lower leverage for R&D intensive companies in the USA, UK, Japan and countries in continental Europe. Aghion et al. (2004) find higher leverage for listed UK companies with R&D activity and that leverage decreases with increasing R&D intensity.

Our analysis is also related to the literature studying the influence of financial constraints on the investment behaviour of companies. Companies are said to be financially constrained if they face higher costs of external as compared to internal finance. The approach of investigating cash-flow investment sensitivities was developed by Fazzari et al. (1988) and applied to German companies by, for example, Harhoff (1998), Audretsch and Weigand (2005) and Audretsch and Eston (2002). Later this approach was also applied to R&D expenditures. For the US, a positive and significant relationship between R&D expenditures and cash-flow is found (Himmelberg and Petersen (1994) and Hall (1992)). Bond et al. (2007) find no influence of cash flow on R&D expenditures of German companies, whereas cash flow influences whether UK companies perform R&D. There are therefore differences between companies in bank-based and market-based systems.

A less closely related strand of the literature uses direct evidence on financing constraints from company surveys. Egeln et al. (1997) find an inverse U-shaped relationship between company age and whether financial restrictions are important obstacles to innovation activities of German companies. The restrictions are most important for companies at the age of 5-10 years. Also for Germany, Winker (1999) finds a negative influence of financing constraints on investment and innovation expenditures. There is evidence from Italy that high-tech firms have a higher probability of being credit constrained than low-tech firms (Guiso (1998)). In a similar fashion, among high-technology firms in the UK the most technologically sophisticated are most likely confronted with financial constraints (Westhead and Storey (1997)). Hartarska and Gonzalez-Vega (2006) find for Russian companies that the availability of internal funds is of higher importance for the investment decision of younger than of older companies.

4 Data

The analysis is based on a panel survey of German small and medium-sized companies conducted by KfW Bankengruppe, Frankfurt/Main, Germany (KfW-Mittelstandspanel). In addition to basic company characteristics, this data set includes information on the innovative activities of companies and their financial structure. Small and medium-sized companies are defined as companies with less than Euro 500 million turnover. There is no minimum number of employees required for the inclusion into the panel. This is a big advantage compared to other data sets, since many surveys impose a size requirement of at least five employees. We find that even the smallest companies report substantive innovative activity; for example, 10% of companies without employees have positive R&D expenditures. It can also be expected that very small companies have more severe financing problems. In order to better understand the relationship between financial structure and R&D activity for SMEs, it is important to observe the very small companies in the data. The survey covers both the manufacturing and the service sector. Companies in the banking and insurance industry are excluded from our analysis.[3]

The sample of the survey was determined with a stratified random sample procedure. The stratification was done according to six size groups (up to 4 employees, 5-9, 10-19, 20-49, 50-99 and 100 or more employees), five industries (manufacturing, construction, retail, wholesale and services), region (Western versus Eastern Germany) and participation in a government support programme for SMEs conducted by KfW Bankengruppe.

Information on 5,795 companies from the first wave collected in 2003 is used for the analysis. The survey achieved a response rate of 17.5%, which is in the typical range for company surveys. A non-response analysis was conducted for the second wave with respect to investment behaviour.[4] The analysis found no relationship between participation in the survey and positive versus zero real investment volume in a given year. We expect that

[3]The R&D figures of very small companies may be less precise than the figures of large companies, since small companies often do not track R&D expenditures explicitly in their accounting system. However, this should not influence our analysis, since a systematic relationship of the imprecision with the the equity ratio is unlikely. There is no indication that small companies would inflate R&D expenditures to hide profits or would deflate sales revenue to appear smaller. Specifically, there is no R&D tax credit in Germany. All regressions contain controls for size.

[4]The second wave can not be included for this analysis, since it contains no information about R&D.

the relationship between the equity ratio and the R&D activity of the companies – which is the main focus of this paper – will also not be affected by the participation decision of the companies. We do not have access to the master data set with information about the companies that did not respond to the survey. We are therefore not able to explicitly control for selection of respondents with a two-step Heckman or similar approach. For the empirical analysis we choose unweighted regression procedures with controls for the stratification variables. There are no weights available that would take the probability of inclusion in our subsamples into account.

5 Descriptive Statistics

Descriptive statistics for the variables are provided in Table 1. The average number of employees measured in full-time equivalents is below 50, since only small and medium-sized companies are covered. The age of the companies has a wide dispersion with an average of 32 years. The equity ratio, defined as book value of equity capital divided by total assets, has an average value of 21%.[5] The R&D intensity, defined as R&D expenditures divided by sales, has a mean of 2.0% and 26% of the companies report R&D activity, i.e. positive R&D expenditures. 31% of the companies are in the manufacturing sector, 18% in construction, 28% in retail/wholesale and 23% in services.

Table 1: Descriptive Statistics

Variable	**Mean**	**Median**	**Stdev.**	**Min**	**Max**
Number of employees	47.7	18.5	82.0	0	948
Company age (in years)	31.7	13	37.5	1	410
Equity ratio (in %)	20.9	15.0	21.1	0	100
R&D intensity (in %)	1.96	0	5.58	0	70
Dummy for R&D activity	0.26	0	0.44	0	1

Source: KfW-Mittelstandspanel, wave of 2003. All values refer to the year 2002.

[5] A small number of companies with negative equity were excluded from the sample. Liabilities can exceed the assets of a company, if repeated losses eat up the equity capital. The company is not closed, if creditors believe that loans can be repaid with future profits. Companies with zero equity were retained.

Table 2: Company Characteristics According to R&D Activity

	Mean			Median	
Variable	R&D	no R&D	Sig. lev. difference	R&D	no R&D
Number of employees	71.0	39.7	< 1% ***	35.5	15
Total assets (in '000 EUR)	8,045	5,985	< 1% ***	3,100	1,450
Total equity (in '000 EUR)	2,085	1,221	< 1% ***	423	168
Company age (in years)	32.2	31.5	73%	13	13
Equity ratio (in %)	22.8	20.3	< 1% ***	18.0	13.0
Equity per owner (in '000 EUR)	1,026	536	< 1% ***	235	100
Number of owners	1.96	1.69	< 1% ***	2	1

Source: KfW-Mittelstandspanel, wave of 2003. All values refer to the year 2002.

In order to get a better understanding of the financing conditions of small and medium-sized companies, we investigate whether there are structural differences between companies with and without R&D activity. Table 2 shows descriptive statistics for both company types. A striking difference is the significantly larger size of R&D performing companies, which is reflected in almost twice the number of employees. The larger size is also indicated by a higher value of total assets and of total equity.[6] There are no significant differences with respect to company age – the difference in the mean is negligible.

The financing choices of both company types vary markedly, illustrating a higher need for equity capital for innovative companies. The equity ratio is 2.5 percentage points higher for companies with positive R&D activity. A difference that is statistically significant at the 1% level. In addition, owners of companies with R&D activity on average invest a substantially higher amount. Equity per owner has a mean of Euro 1,026,000 for companies with and of Euro 536,000 for companies without R&D activity. In order to raise enough equity, companies can tap the personal funds of several owners. This possibility is reflected in a higher number of owners in innovative companies. Both the differences in equity per owner and in the number of owners are significant at the 1% level.

[6]The size difference cannot be explained with companies being larger in industries that typically perform more R&D as the difference still exists after controlling for industry effects.

The differences in the equity ratio between companies with and without R&D can also be seen in Figure 1. The equity ratio of R&D performing firms is higher in all age groups than the equity ratio of non R&D performing firms. The equity ratio increases continually up to the age group containing companies with a maximum age of 50 years, because companies use profits to pay back bank loans and to increase the equity capital through retained earnings. For R&D performing firms the data show a decrease for very old companies.

Finally, for R&D performing companies we investigate R&D intensities according to age and size in Table 3. We find that young and small companies have substantially higher R&D intensities on average than old or large companies. Some of the young companies are presumably still in the process of introducing their products in the market and therefore have only limited sales. It is interesting to note that the median R&D intensity is identical across subgroups. The differences between the subgroups therefore occur at the higher end of the distribution.

Figure 1: The Relationship Between Equity Ratio and Age

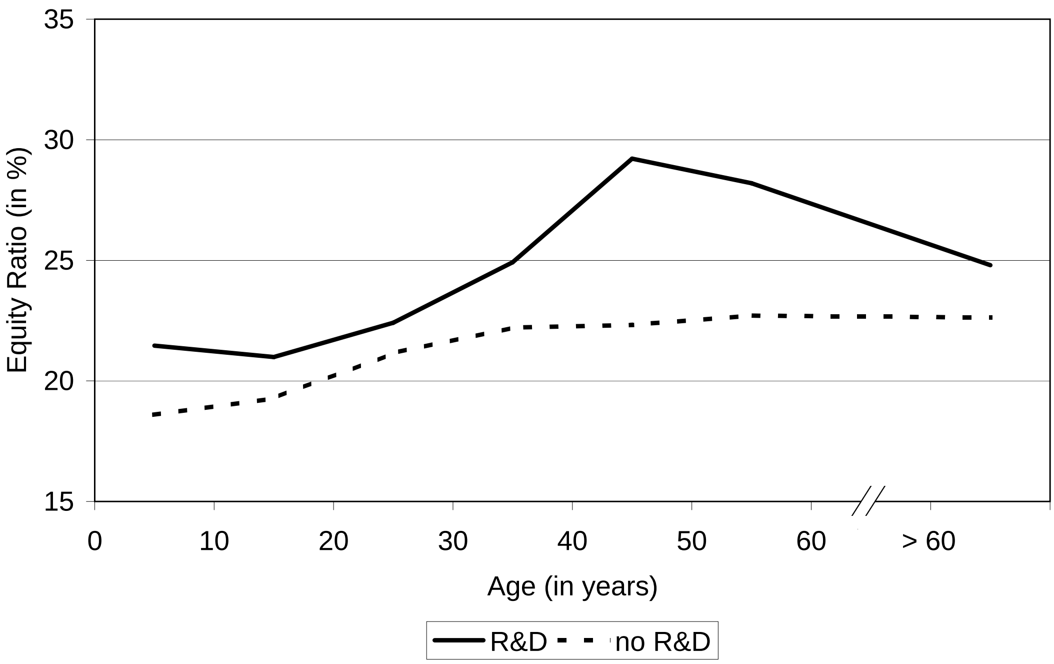

Table 3: R&D Intensity of Subgroups

Subgroup	R&D Intensity Mean	R&D Intensity Median	No. of obs.
Young companies (<= 10 years)	10.0	5.0	473
Old companies (> 10 years)	6.51	5.0	1016
Small companies (<= 20 employees)	10.3	5.0	548
Large companies (> 20 employees)	6.09	5.0	941

Source: KfW-Mittelstandspanel, wave of 2003. All values refer to the year 2002. Only companies with positive R&D expenditure are included.

6 The Importance of Equity Finance for R&D Activity

6.1 Empirical Model

For the empirical analysis we first employ a Tobit model with the R&D intensity as dependent variable. It takes account of the fact that many companies report zero values of R&D expenditure. In the Tobit model regressors have the same influence on the probability of doing a positive amount of R&D as on the R&D intensity itself, a restriction that is lifted in the second model. The hurdle model (see Cragg (1971)) consists of two parts: the first is a probit model showing influences on the probability of having positive amounts of R&D expenditure; the second is a Tobit model restricted to companies with positive R&D. The separation into two parts allows for more flexibility. If there are differences either in the size of the influence of explanatory variables or in their significance, the hurdle model makes them transparent.

6.2 Controlling for Reverse Causality

Our estimates can be influenced by reverse causality. Not only can equity capital be a prerequisite for R&D activity, it is also possible that companies with R&D activity select a capital structure with a higher proportion of equity, since bank loans can be more expensive for riskier companies. Also, companies with R&D activity can have difficulties with obtaining a bank loan at all.

In order to identify the effect of the equity ratio on the R&D activity, we use instruments. The first instrument is the local banking competition. Theoretically, more intense competition in the banking sector can have two effects. It can improve the availability of bank loans if banks spend more resources to identify good companies in order to keep their market share. It can also decrease the availability of loans, since companies can more easily switch from one bank to the other. Banks therefore find it harder to obtain rents from ongoing customer relationships with good companies and may therefore be less willing to extend loans to new companies.[7] The availability of loans influences the equity ratio of the companies. If loans are more easily available, companies will operate with a lower equity ratio.

We define banking competition at the district level as the number of banks active in a district divided by the population of the district. Data on the number of banks and their branches at the district level are obtained from the Bundesbank, the former German central bank. Since districts are of varying size and more banks will be active in larger districts, we use the population to normalize the variable.[8] The number of banks active in a district corresponds to the number of banks that have at least one branch in this district. For example, Deutsche Bank is not only active in Frankfurt/Main, but in each district where it operates a branch.

Whereas it is difficult to imagine that banking competition should have a direct influence on the R&D activity of companies, there are possibly indirect influences. Banking competition may be higher in districts with a higher income per capita, because the market is more lucrative. A higher income can be an indicator for a well educated population, which can be related to a higher average R&D intensity of the companies in the district, since R&D intensive companies find it more attractive to settle in districts where they can find a well educated work force. In the instrumental variable regressions we therefore control for the income per capita at the district level and include dummies for a classification of districts into nine categories according to urban or rural type. It is also conceivable that the industrial structure of a region influences both R&D intensity and banking competition. We control

[7]Petersen and Rajan (1995) develop this argument and provide empirical evidence for this effect for US banks. However, for the German capital market with a strong relationship between the company and a single bank ("Hausbankprinzip") it can be assumed that this argument is less relevant.

[8]Germany is divided into 439 districts (Kreis or kreisfreie Stadt). Berlin is the largest district with a population of 3.4 million and Zweibrücken is the smallest district with a population of 36,000.

for this possibility by including the share of employees working in the manufacturing sector as regressor.[9]

We calculate a second set of estimates with the instrument financial standing of the companies to test the robustness of our results. The information is obtained from Germany's largest credit rating agency, Creditreform, and then merged to the KfW-Mittelstandspanel. The financial standing is an element of the overall credit rating. It is coded from one for the best standing to six for the worst. Suppliers of trade credit can enquire at Creditreform about the financial standing of their customers to help them with their credit decision. Since banks prefer to lend to good risks, the rating also gives an indication of how easy a company will find it to obtain bank loans. This instrument should therefore be correlated with the endogenous variable equity ratio. On the other hand, Creditreform uses no information about R&D activity to determine the financial standing. The instrument should therefore not be correlated with the error term of the second-stage regressions.

In the regressions we also control for whether companies participated in a government support programme conducted by KfW Bankengruppe and whether companies have limited liability. It can be argued that both variables are potentially endogenous. There is a large literature on the selection of companies into programmes to support R&D (see, for example, Busom (2000)). However, the programmes here are not related to R&D activities but support the general investment activities of existing and newly founded companies. The programmes are therefore not related to the main aspect of our analysis. The legal form of a company may be chosen simultaneously with R&D activity. Since we do not have appropriate instruments for legal form, we cannot control for the potential endogeneity of this variable.

The results of the first-stage regressions are reported in Table 4. Column (1) reports the results for the use of banking competition. A higher degree of competition leads to a significantly lower equity ratio, i.e. the supply of bank loans improves with competition. Column (2) shows that companies with a better financial standing have a higher equity ratio. The instrument is significant to the 1% level.[10]

[9] Income per capita, population figures and share of employees in the manufacturing sector are taken from Statistik regional 2004, German National Statistical Offices (Statistische Ämter des Bundes und der Länder). The categorization of districts follows INKAR 2004, Federal Office for Construction and Regional Planning (Bundesamt für Bauwesen und Raumordnung).

[10] Staiger and Stock (1997) suggest the rule of thumb that instruments are weak, if the test of excluded

Table 4: First Stage Regression Results

	(1)		(2)	
Dep. variable	Equity ratio			
Local banking competition	-1.421**	(0.708)		
Financial standing			-0.267***	(0.053)
No of employees	-0.003	(0.006)	-0.007	(0.007)
Square no of employees	0.000	(0.000)	0.000*	(0.000)
Age	0.094***	(0.015)	0.096***	(0.019)
Square age	-0.000***	(0.000)	-0.000***	(0.000)
No of observations	5,795		4,288	
R^2	0.043		0.050	
Partial R^2 of excl. instruments	0.001		0.005	
Test of excl. instruments	4.0** F(1, 5736)		25.8*** F(1, 4239)	

Note: All regressions contain a dummy for whether the company participated in a government support programme, a regional dummy and industry dummies comparable to the 3-digit SIC level. The regression in column (1) also contains controls for income per capita at district level, for the share of employees working in the manufacturing sector at district level and eight dummies for district type. Robust standard errors are in parentheses. *, **, *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively.

6.3 Estimates without Instruments

In Table 5 column (1) we present the results of the Tobit model and in columns (2) to (3) the results of the hurdle model. We find a positive and significant relationship between equity ratio and R&D activity for the Tobit model and for the first part of the hurdle model covering the probability of R&D. For the R&D intensity restricted to R&D performing companies we find a positive but insignificant effect. These results can be influenced by reverse causality since the equity ratio is not instrumented. The equity ratio and the number of employees are scaled differently in the statistical analysis than in Table 1: equity ratio is expressed as a ratio and the number of employees is in '000.[11]

instruments has an F smaller than 10. The instrument financial standing passes this test, but the instrument banking competition does not pass. However, using both instruments individually we obtain similar results.

[11] The marginal effects in Tables 5 to 7 are calculated with the Stata procedure mfx (Stata (2007, p. 269)). The equations for the marginal effects can be found in Maddala (1983, p. 23 and p. 160).

Table 5: Regression Results Without Instruments – Marginal Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Tobit	Hurdle model		Tobit	Hurdle model	
Dep. variable	R&D int. ≥ 0	R&D dummy	R&D int. > 0	R&D int. ≥ 0	R&D dummy	R&D int. > 0
Equity ratio	0.560**	0.064**	0.932	0.219	0.039	0.173
	(0.250)	(0.027)	(0.778)	(0.267)	(0.031)	(0.837)
Equity ratio * Dummy young				0.940**	0.069	2.242*
				(0.42)	(0.045)	(1.248)
No of employees	5.008***	1.152***	-12.52***	5.204***	1.166***	-11.991***
	(0.120)	(0.167)	(2.756)	(1.238)	(0.167)	(2.72)
Square no of employees	-0.006**	0.001***	0.014***	0.006***	-0.001***	0.013***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	-0.013***	-0.001***	-0.038***	-0.010***	-0.001***	-0.032***
	(0.003)	(0.000)	(0.006)	(0.003)	(0.000)	(0.006)
Square age	0.000***	0.000*	0.000***	0.000***	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummy limited liability	0.752***	0.093***	-0.310	0.757***	0.094***	-0.292
	(0.115)	(0.013)	(0.457)	(0.115)	(0.013)	(0.457)
Dummy support programme	0.009	0.016	-0.550*	0.012	0.016	-0.548*
	(0.103)	(0.012)	(0.285)	(0.103)	(0.012)	(0.284)
Dummy Eastern Germany	-0.141	-0.018	0.097	-0.129	-0.017	0.101
	(0.102)	(0.012)	(0.271)	(0.102)	(0.012)	(0.270)
No of observations	5,795	5,795	1,489	5,795	5,795	1,489
Log likelihood	-7,409	-2,704	-5,221	-7,406	-2,703	-5,219
Pseudo R^2	0.067	0.181	0.025	0.067	0.182	0.026
Mean dep. variable	1.96	0.26	7.62	1.96	0.26	7.62
ME equity ratio * sd equity ratio	0.117	0.013				
ME equ. rat. * Dummy young * sd equ. rat.				0.196		0.469

Note: Dummy young equals one for companies up and including the age of 10 years. Dummy support programme equals one for companies that participated in government programmes to support financing. Dummy Eastern Germany equals one for companies located in the Eastern part of Germany. All regressions contain industry dummies comparable to the 3-digit SIC level. Equity ratio is expressed as ratio. Number of employees is in '000. The marginal effects (m.e.) show how the expected value of the dependent variable changes with a marginal change of the independent variable and are calculated for the mean values of the explanatory variables. M.e. in column (1) and (4) are calculated for the unconditional expectation of R&D expenditure. M.e. in column (3) and (6) are calculated for the expectation of R&D expenditure conditional on R&D expenditure being positive. For the dummy variables in columns (1) to (6) the discrete change in the dependent variable for a change from zero to one is given. Robust standard errors are in parentheses. *, **, *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively.

Evaluated at the mean of the number of employees we find a positive and significant influence of size on R&D for the models of columns (1) and (2) and a negative and significant influence for column (3). Large companies therefore have a higher probability of pursuing R&D but have lower R&D intensities. The age variable has a negative and significant effect at its mean in all three models. The control for limited liability shows a positive and significant influence on the probability of R&D, but has no significant influence on the R&D intensity of R&D performing companies. We also control for participation in a government support programme, a regional indicator and industry classification, because these variables were used to stratify the random sample.

Columns (4) to (6) contain the same econometric models with an interaction term allowing for a different influence of the equity ratio for young and old companies.[12] A company is defined as young if it is ten years old or younger. The standard Tobit regression shows no significant influence of the equity ratio for old companies. For young companies we find a significant effect. The sum of the coefficients of the basis and interaction term of the equity ratio is significant at the 1% level. Furthermore, the effect is significantly larger for young than for old companies. There is now no significant influence of the equity ratio on the probability of performing R&D for either young or old companies. It is possible that the strength of the influence is not sufficient any more once the sample is split according to age. For the Tobit specification considering only companies that are active in R&D we again find a significant influence of the equity ratio on the R&D intensity for young but not for old companies. The influence of the equity ratio is significantly higher for young than for old companies. The analogous specification without age interaction does not show a significant effect, since the relationship for young companies is confounded by the lack of a relationship for the old companies. Since we use no instruments here, it is not clear whether this result should be interpreted as indicating equity as a necessary financing type for R&D or as R&D intensity influencing the financial structure of the young companies.

6.4 Estimates with Instruments

In order to identify the direction of causality, we instrument the variable equity ratio. Table 6 presents results with local banking competition used as an instrument. The specifications in

[12]The sample contains 1,873 companies up to the age of 10 years (32% of the total).

columns (1) to (3) without interaction terms now show no significant influence of the equity ratio. The difference in the results can give an indication of the direction of causality. The lack of significance for the instrumented probit regression can mean that the availability of equity financing does not influence the decision whether to perform R&D, whereas companies active in R&D do indeed choose a financial structure with more equity. The insignificance of the equity ratio could also mean that the instrument is too weak. In the instrumented regressions some of the additional control variables lose their significance, but the ones that remain significant always keep their sign.

Columns (4) to (6) present the results of the regressions with an interaction term. As in the regressions without instruments, the Tobit model shows a significantly larger influence of the equity ratio for young companies, but the sum of the basis and interaction term is not significant any more. The hurdle model of columns (5) and (6) gives additional insights, since it allows for separate influences on the probability of R&D activity and on the R&D intensity. The first part of the hurdle model shows no significant influence of the equity ratio on the decision to undertake R&D. In the second part of the hurdle model, where only companies with R&D activity are considered, we find a significantly larger influence of the equity ratio for young companies. As in the Tobit model of column (4), the sum of the basis and the interaction term is not significant. This can be due to a weak correlation of the instrument banking competition with the equity ratio. Future research may be able to provide more precise estimates of this relationship. The influence of the equity ratio on the R&D intensity is economically important. For old companies an increase in the equity ratio of one standard deviation increases the R&D intensity by 4.5 percentage points. The standard deviation, measured as a ratio, is equal to 0.21. The effect for young companies is about 20% larger. Here an increase in the equity ratio of one standard deviation leads to an increase in the R&D intensity of 5.3 percentage points. This is a large effect given that the mean of the R&D intensity of R&D performing companies is 7.6%.

The results of the hurdle model suggest that managers only choose to start large R&D projects if they have the necessary financial resources to bring them to successful completion. Equity financing is especially important for companies with high R&D intensity, for example for high-tech firms. If R&D is only a minor part in the overall activities of the company, then there is no requirement of having a higher equity ratio to finance the R&D activities.

Table 6: Regression Results With Instrument Banking Competition – Marginal Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Tobit	Hurdle model		Tobit	Hurdle model	
Dep. variable	R&D int. ≥ 0	R&D dummy	R&D int. > 0	R&D int. ≥ 0	R&D dummy	R&D int. > 0
Equity ratio	-5.655	-1.048	22.861	-6.192	-1.082	21.476
	(8.621)	(1.042)	(26.333)	(8.617)	(1.042)	(26.286)
Equity ratio * Dummy young				1.185*	0.070	4.059**
				(0.657)	(0.075)	(1.949)
No of employees	4.860***	1.123***	-12.196***	5.017***	1.133***	-11.651***
	(1.200)	(0.017)	(2.750)	(1.200)	(0.017)	(2.790)
Square no of employees	-0.006**	-0.001***	0.012***	-0.006**	-0.001***	0.012**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	-0.007	0.000	-0.059**	-0.037	0.000	-0.047*
	(0.008)	(0.001)	(0.026)	(0.086)	(0.001)	(0.026)
Square age	0.000	-0.000	0.000**	0.000	-0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummy limited liability	0.648***	0.076***	-0.121	0.654***	0.076***	-0.114
	(0.161)	(0.020)	(0.539)	(0.159)	(0.020)	(0.535)
Dummy support programme	-0.296	-0.039	0.592	-0.311	-0.040	0.565
	(0.456)	(0.054)	(1.330)	(0.458)	(0.054)	(1.331)
Dummy Eastern Germany	0.224	0.041*	-0.491	0.232	0.041*	-0.512
	(0.212)	(0.025)	(0.639)	(0.213)	(0.025)	(0.639)
No of observations	5,795	5,795	1,489	5,795	5,795	1,489
Log pseudolikelihood	-7,401	-2,695	-5,216	-7,399	-2,694	-5,213
Pseudo R^2	0.068	0.184	0.026	0.068	0.184	0.027
Mean dep. variable	1.96	0.26	7.62	1.96	0.26	7.62
ME equity ratio * sd equity ratio						
ME equ. rat. * Dummy young * sd equ. rat.				0.248		0.848

Note: Dummy young equals one for companies up and including the age of 10 years. Dummy support programme equals one for companies that participated in government programmes to support financing. Dummy Eastern Germany equals one for companies located in the Eastern part of Germany. All regressions contain industry dummies comparable to the 3-digit SIC level. Controls for income per capita at district level, for the share of employees working in the manufacturing sector at district level and eight dummies for district type are included. Equity ratio is expressed as ratio. Number of employees is in '000. The marginal effects (m.e.) show how the expected value of the dependent variable changes with a marginal change of the independent variable and are calculated for the mean values of the explanatory variables. M.e. in column (1) and (4) are calculated for the unconditional expectation of R&D expenditure. M.e. in column (3) and (6) are calculated for the expectation of R&D expenditure conditional on R&D expenditure being positive. For the dummy variables in columns (1) to (6) the discrete change in the dependent variable for a change from zero to one is given. Robust standard errors are in parentheses. *, **, *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively.

The level of overall risk is possibly low enough in these firms for banks to be willing to extend loans. Another explanation could be that these companies can pledge enough collateral from other activities to satisfy the requirements of the bank for financing their low intensity R&D activities.

The influence of the equity ratio is somewhat larger for young than for old companies. Whereas old companies have had time to build up equity via retained profits, young companies have to rely on the original investment made by the owners. In addition, older and more diversified companies can finance part of their R&D activity with bank loans, since they can provide collateral from other business activities. Evidence by Scott (2000*b*) for US companies is consistent with this interpretation of our findings. It shows that younger companies and companies with managers lacking business experience have a lower probability of using outside equity financing for R&D projects. The younger companies depend on their own equity to finance their activities.

Table 7 shows results with the instrument financial standing. For the first part of the hurdle model in column (5) we again find no signficant influence of the equity ratio on the probability of pursuing R&D. For the second part of the hurdle model in column (6) the size of the difference in the influence of the equity ratio between young and old companies is very similar. However, the basis term of the equity ratio has a much smaller coefficient when estimated with the instrument financial standing. Whereas companies in Eastern Germany had a significantly higher probability of pursuing R&D when using the instrument banking competition, there is no significant difference between companies from Eastern and Western Germany when the instrument financial standing is used. Differences in the estimates can be due to differences in how well the instruments are correlated with the equity ratio.

Unfortunately, our analysis does not provide direct evidence on whether companies are restricted by the availability of equity capital. If the original owners cannot increase their investment because of exhausted personal funds, it is, in principle, possible to admit additional owners to increase the equity capital available to the company. However, it is often not easy to find a person who is willing to invest his or her funds in a risky firm and who fits into the existing team of owners. The availability of seed or early-stage financing from venture capitalists is limited in Germany as well as in many other countries. In addition, even if outside equity financing is available, owners may be reluctant to take it up, because

Table 7: Regression Results With Instrument Financial Standing – Marginal Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Tobit	Hurdle model		Tobit	Hurdle model	
Dep. variable	R&D int. ≥ 0	R&D dummy	R&D int. > 0	R&D int. ≥ 0	R&D dummy	R&D int. > 0
Equity ratio	-2.542	-0.259	2.117	-2.661	-0.266	2.063
	(3.427)	(0.442)	(9.081)	(3.427)	(0.443)	(9.066)
Equity ratio * Dummy young				1.243*	0.059	4.551**
				(0.74)	(0.085)	(2.356)
No of employees	4.702***	1.155***	-10.739***	4.864***	1.163***	-10.118***
	(1.250)	(0.190)	(2.961)	(1.265)	(0.190)	(3.062)
Square no of employees	-0.000*	-0.000**	0.013*	-0.000*	-0.000**	0.012**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	-0.012**	-0.001*	-0.038**	-0.009*	-0.001	-0.027**
	(0.005)	(0.001)	(0.012)	(0.005)	(0.001)	(0.011)
Square age	0.000*	-0.000	0.000**	0.000	0.000	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Dummy limited liability	0.656***	0.083***	0.136	0.663***	0.083***	0.157
	(0.141)	(0.018)	(0.475)	(0.141)	(0.018)	(0.470)
Dummy support programme	-0.127	0.000	-0.386	-0.117	0.001	-0.326
	(0.198)	(0.025)	(0.517)	(0.198)	(0.025)	(0.520)
Dummy Eastern Germany	-0.190	-0.023	-0.158	-0.192*	-0.023	-0.226
	(0.117)	(0.015)	(0.297)	(0.116)	(0.015)	(0.293)
No of observations	4,288	4,288	1,113	4,288	4,288	1,113
Log pseudolikelihood	-5,454	-1,979	-3,835	-5,452	-1,979	-3,831
Pseudo R^2	0.073	0.194	0.029	0.073	0.194	0.030
Mean dep. variable	1.92	0.26	7.41	1.92	0.26	7.41
ME equity ratio * sd equity ratio						
ME equ. rat. * Dummy young * sd equ. rat.				0.260		0.951

Note: Dummy young equals one for companies up and including the age of 10 years. Dummy support programme equals one for companies that participated in government programmes to support financing. Dummy Eastern Germany equals one for companies located in the Eastern part of Germany. All regressions contain industry dummies comparable to the 3-digit SIC level. Equity ratio is expressed as ratio. Number of employees is in '000. The marginal effects (m.e.) show how the expected value of the dependent variable changes with a marginal change of the independent variable and are calculated for the mean values of the explanatory variables. M.e. in column (1) and (4) are calculated for the unconditional expectation of R&D expenditure. M.e. in column (3) and (6) are calculated for the expectation of R&D expenditure conditional on R&D expenditure being positive. For the dummy variables in columns (1) to (6) the discrete change in the dependent variable for a change from zero to one is given. Robust standard errors are in parentheses. *, **, *** indicate statistical significance at the 10, 5, and 1 percent levels, respectively.

they do not want to share control of the company. This last point is also an argument against an investment by venture capitalists, since they demand influence as well. Hence, owners of companies may be only willing to engage in substantial R&D activities if enough equity is available or if the returns of the R&D project are high enough to make the acquisition of additional equity feasible and worthwhile. Scott (2000*a*) finds evidence that supports the direction of causality of our analysis from equity finance to R&D intensity. Owners of US companies participating in the SBIR programme reported that they were looking for outside financing, needed it and were constrained in their R&D activities by its absence.

In some situations the required returns for obtaining new equity from additional owners or venture capitalists may be too high. Companies may then refrain from undertaking R&D. Since R&D projects have positive externalities (Arrow (1962)), there may be a reason for the government to support the R&D activities of companies. For some companies the social rate of return on projects may be higher than the opportunity costs of equity capital, whereas the private rate of return may be lower. Governments could try to improve the access to equity capital or could initiate support programmes that provide cheaper equity capital.

6.5 Robustness Checks

The results of our analysis are robust to a number of variations in the regression specification. We obtain identical results if we use alternative measures of local banking competition as an instrument. We try the Herfindahl index and the sum of the three largest market shares, each at the district level. The market share of a bank is measured as the number of subsidiaries a bank has in a district divided by the total number of subsidiaries in the district.

We also experiment with different cut-off points for the classification of a young company. There is a trade-off between including only very young companies and thereby reducing the number of observations and extending the range to older companies and possibly blurring the effects of young age. We obtain identical results if we restrict the category of young companies to a maximum age of eight years. We find a change in the results, if we include companies up to the age of 12. The differential effect for young companies becomes much smaller and is insignificant.

Finally, we exclude companies from the analysis that report an equity value of zero. The results also remain identical with this change.

7 Conclusions

In this paper we provide evidence on the relationship between the capital structure of SMEs and their R&D activities. We find no significant influence of the equity ratio on the probability of pursuing R&D. However, for R&D performing companies the equity ratio has a positive influence on the R&D intensity. This influence is larger for young companies. In order to control for reverse causality we alternatively use the variable local banking competition and the variable financial standing as instrument for the equity ratio. Our results suggest that low levels of R&D activity do not require substantially higher levels of equity financing. However, companies with high R&D intensities, such as high-tech firms, need more equity capital. These companies are therefore more dependent on a functioning market for external equity.

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