Causes and Effects of Financing Constraints at the Firm Level

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ABSTRACT. This paper focuses on the empirical assessment of determinants and effects of financing constraints at the firm level. Using a standard model of credit rationing based on asymmetric information firm age and size are found to be factors which should influence the probability of financing constraints. Improving business conditions strengthen the degree of informational asymmetry. A unique panel of firm data for Germany, including direct information on financing constraints, is used for the econometric analysis. Firms' size and improving business conditions are found to have a significant effect. Furthermore, a significant impact on investment and R&D expenditures cannot be rejected.

1. Introduction

If bank loans and other forms of external and internal financing are not perfect substitutes at the firm level, restricted access to bank loans may result in a financing deficit. The approach of asymmetric information, formalized for the loan market by Stiglitz and Weiss (1981), offers a rationale for the existence of such a limited access to external finance. It is assumed that banks can classify firms according to their creditworthiness only at a coarse level. The classification is based on observable features, such as past success, age or duration of business relations. The actual probability of a single firm repaying its loan is unknown to the banks; they merely know the distribution of the repayment probabilities within a given group of firms. Under this setting, the loan rate does not only influence the quantity of loan demand, but also its quality due to adverse selection or adverse incentive effects.[1] Consequently, profit maximization might lead to interest rates lower than the market equilibrium rate which, in turn, results in restricted access to bank loans, at least for some firms.

If the incidence of credit constraints is not purely random, but rather concentrated on some groups of firms,[2] and if firms have to react to such constraints due to an overall financing deficit, changes in bank loan supply can have real effects. The focus of this paper, therefore, is to identify characteristics of firms more likely to face restricted access to bank loans, and to test whether this restriction imposes reactions on their investment and R&D expenditures.

Among the characteristics which might influence the rationing probability are the age and size of firms, as well as their ongoing business relations to banks. There is large theoretical literature on this topic and it is beyond the scope of this paper to give an extensive review.[3] Instead, it is argued that the impact of firm age can be derived directly from the textbook Stiglitz and Weiss model. Furthermore, a slight extension of the model allows us to analyze the impact of business expectations at the firm and sectoral level.

The main contribution of this paper lies in the empirical assessment of the causes of financing constraints and their real effects. A unique firm panel data set for the German manufacturing sector supplied by the ifo institute for economic research, Munich, is used for this purpose. In contrast to most of the data sets used in prior research,[4] the data here contain direct information on the existence of financing deficits at the firm level.[5] This feature of the data represents a distinct advantage for two reasons. First, it avoids the use of proxies for the existence of financing constraints, which was subject to the recent controversy about the Fazzari, Hubbard and Petersen (1988) results in Kaplan and Zingales (1997) and

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Fazzari, Hubbard and Petersen (1996). Second, it enables us to analyze cause and effect of financing constraints separately.

The data for 1919 firms or operational units and the time period 1982–1991 also include information on selected firm characteristics, such as employment, sales, sector, investment and expenditures for innovative activities. Furthermore, estimates of the current business situation and business expectations are covered. However, some shortcomings of the data set discussed in section 3 require the use of proxies for some variables of interest, e.g. firm age.

The paper is organized in the following way: Section 2 provides a sketch of the Stiglitz and Weiss model and its extension, which allow us to derive some hypotheses on the determinants of financing constraints. The ifo firm panel used for the empirical assessment is described in section 3. The econometric models for these microdata are presented in section 4; and the estimation results are discussed in section 5.

2. Theory of credit rationing

2.1. *Adverse selection and adverse incentives*

The more recent literature on credit rationing stresses the argument of incomplete or asymmetric information (cf. Jaffee and Stiglitz (1990) and the literature cited therein). Potential debtors know the probability distribution of the returns of their own projects whereas the banks know only the aggregate distribution for all firms in a specific group.

In standard loan contracts, the bank's expected return depends on the interest rate charged and on the repayment probability, since, in case of insolvency, repayment is limited. If, for a group of firms with identical expected gross returns, the mean of the repayment probability is given, the bank's expected return will decrease with a growing variance of the repayment probabilities, while a firm's expected net return, i.e. the gross return minus the repayment to the bank, will increase with the variance of the gross returns.

Now, consider a given group of firms with interest elastic loan demand. If a bank increases its interest rate, the expected net return for firms with relatively riskless projects will become zero or negative. They will no longer seek a loan. Consequently, an increase of the interest rate will lead to a decrease in the overall repayment probability for the firms still requesting a loan. *Adverse selection* takes place, which might be attributed to unrevealable information. Eventually, a further increase in the interest rate will lead to a decrease in the bank's expected return.

If firms can choose between projects with differing risks and banks only know the distribution of the risks over the projects, a similar effect may arise: An increase of the interest rate will give an incentive to choose riskier projects. The expected return to the bank might eventually decrease due to this effect. These *adverse incentives* are also called "moral hazard". They might also be described as effects of hidden action.

2.2. *The Stiglitz-Weiss model*

In order to derive the impact of some firm characteristics on the risk of facing financing constraints, a sketch of the basic model by Stiglitz and Weiss (1981) for the adverse selection effect is presented (cf. Blanchard and Fischer (1989), pp. 480ff, for some details).

Each firm, out of a continuum of firms, disposes of exactly one project which requires an initial endowment of K, where firms' equity $W < K$. Consequently, external finance of $B \equiv K - W$ is necessary. It is offered by identical, competitive, risk neutral and expected profit maximizing banks in form of standard loan contracts at interest rate r.[6]

The project of firm i succeeds with probability p_i and gives a return of R_i^s. The return to a failed project is equal to R^f for all firms. While the firms differ with regard to the success probability, the expected gross return is identical and equal to $R = p_i R_i^s + (1 - p_i)R^f$ for all projects. Consequently, a high return to a successful project R_i^s corresponds to a low success probability p_i. If the project of a firm consists of an investment plan including several smaller projects, risk diversification will lead to higher overall success probability p_i.

The expected net return of firm i is given by

$$E(\pi_i) = p_i[R_i^s - (1 + r)B] \quad (1)$$

$$= R - R^f - p_i[(1 + r)B - R^f]. \quad (2)$$

Thus, for given expected gross return R the expected net return of firm i decreases with the

success probability p_i. Consequently, firms with riskier projects will ceteris paribus accept higher interest rates on loans. If they have the alternative to invest their initial endowment W in a secure asset, with rate of return ρ, risk neutral entrepreneurs will prefer their investment project as long as

$$E(\pi_i) \geq (1 + \rho)W. \tag{3}$$

Thus, an increase in the interest rate r will ceteris paribus result in a higher risk of the marginal project, i.e. the project at which an entrepreneur is indifferent between undertaking it or choosing the secure asset. Let p^* denote the success probability of the marginal project, i.e. $E(\pi_i) \geq (1 + \rho)W \iff p_i \leq p^*$. Then, it follows that $dp^*/dr < 0$.

Now, the central assumption on asymmetric information comes in. It is assumed that for a group of firms with identical observable characteristics banks know solely the distribution function $F(p)$ of the p_i in this group, while the firms themselves know their success probability p_i. It is impossible for the banks to distinguish between the firms in such a group with regard to their risk.

However, since only firms with a success probability of less than p^* will ask for a loan, the bank's expected return is given by

$$\begin{aligned} E(\pi_b) &= (1 + r)B \frac{1}{F(p^*)} \int_0^{p^*} pf(p)dp \\ &\quad + R^f \frac{1}{F(p^*)} \int_0^{p^*} (1 - p)f(p)dp \\ &= [(1 + r)B - R^f] \frac{1}{F(p^*)} \int_0^{p^*} pf(p)dp \\ &\quad + R^f, \end{aligned} \tag{4}$$

where $F(p^*)$ is the fraction of firms demanding a loan at the given interest rate r and $f(p)$ denotes the density function corresponding to $F(p)$.

Using $dp^*/dr < 0$ and differentiating (4) with regard to r it can be shown that for any given density function f there always exists an interest rate for which the positive effect of higher repayment commitments due to the increase in the interest rate is overcompensated by the decrease in the repayment probability. Profit maximizing banks will choose r with $dE(\pi_b)/dr = 0$, which is not necessarily the market clearing price for a given loan supply.

2.3. *A simple cohort model*

Despite these adverse selection problems, banks may still discriminate groups of firms according to some observable characteristics. Both the theoretical and empirical literature stress the importance of the age of firms as mentioned in the introduction. The model just introduced offers a straightforward option to motivate the influence of this variable without having to rely on information accumulation due to ongoing business relations.

Therefore, it is assumed that in each period a continuum of new firms with the features described above enters the market. Old firms continue operation unless they go bankrupt. While the density of success probabilities for new firms is given by $f(p)$, it evolves over time for a cohort of enterprises starting up business in the same period, as firms with a low repayment probability have a high risk of leaving the market due to bankruptcy. For a cohort of firms being in the market for n periods the density becomes

$$f_n(p) = \frac{f(p)p^n}{\int_0^1 f(p)p^n dp}. \tag{5}$$

Figure 1 illustrates the development of the repayment distribution for a cohort of firms. For the example, $f(p)$ was chosen as a curtailed normal density on [0.5, 1] with mean 1 and standard deviation 0.15. As can be seen, the fraction of low risk firms increases, whereas the fraction of high risk firms (p close to 0.5) decreases rapidly. This obvious result is supported by the empirical findings on firm failures in Evans (1987), Dunne, Roberts and Samuelson (1989), Audretsch (1991, 1997) and Wagner (1994).

Using the model introduced in section 2, the expected return of a credit to a newly founded firm is given by equation (4), and to a firm operating for n years as

$$\begin{aligned} E(\pi_b) &= (1 + r)B \frac{1}{F_n(p^*)\kappa_n} \int_0^{p^*} p^{n+1} f(p)dp \\ &= R^f \frac{1}{F_n(p^*)\kappa_n} \int_0^{p^*} (1 - p)p^n f(p)dp, \end{aligned} \tag{6}$$

where p^* is implicitly defined as above, F_n is the distribution function corresponding to f_n and $\kappa_n \equiv \int_0^1 f(p)p^n dp$ for n in $\mathbb{N}$.

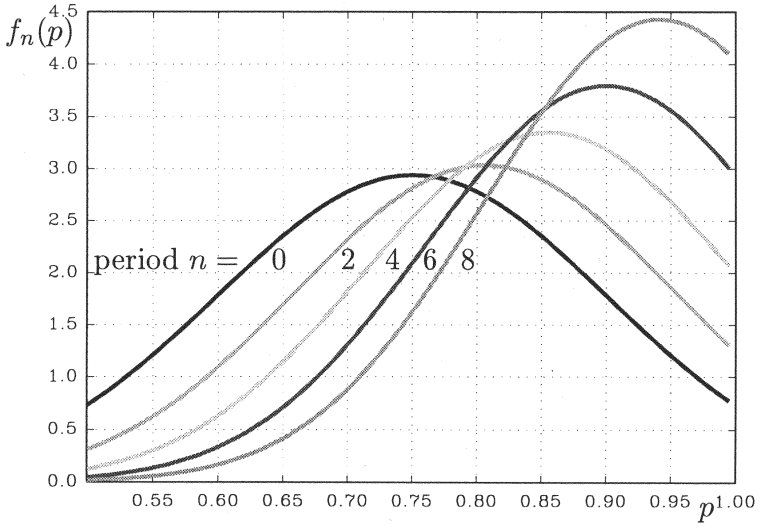

Figure 1. Densities of repayment probabilities.

The simple proof of the following proposition is given in Appendix A:

Proposition 2.1. If $p^* > 0$, i.e. if there is a demand for loans at the given interest rate, then for all $n > 0$ $E_n(\pi_b) > E(\pi_b)$.

Consequently, banks facing an excess demand for loans at the given interest rate will, ceteris paribus, i.e. after controlling for other observable characteristics, prefer "old" firms.

2.4. *Business prospects and loan demand*

In order to analyze the impact of business prospects, another stochastic element is introduced. Now, the return to a successful project of firm i is given by $(1 + \delta_i)R_i^s$ with $\delta_i \in \{-\nu, 0, \nu\}$, $\nu > 0$ and $E(\delta_i) = 0$. While the mean expected return over all firms within the group remains unchanged, the expected project return is no longer assumed to be identical over firms.[7] However, only firms possess information about δ_i prior to investment. The information set of banks remains unchanged introducing an additional source of asymmetry in information.

An analysis of the expected return of firm i along the lines depicted in equations (1) to (3) shows that the marginal success probability p^* rises for $\delta_i = \nu$ and becomes smaller for $\delta_i = -\nu$. This effect is not linear and it can be shown that the overall influence on the marginal success probability for a given group of firms is positive. The details are given in Appendix B. Hence, the bank optimal loan rate is larger in this case; loan supply will rise and the overall rationing probability decrease. The additional information at the firm level has an incentive compatible influence. This effect, however, should not be confounded with the effect of improving business prospects for the whole group, which corresponds to a higher mean expected return. This case is more likely to be observable by banks, and then, reduces the rationing probability for the whole group.

Still, rationing might occur for some group of firms. Due to the differences in the marginal success probabilities, for any given interest rate, the share of firms with $\delta_i = \nu$ asking for a loan is larger than in the whole group of firms. Consequently, since banks have no information on the δ_i, the probability of measuring financing constraints for an individual firm will rise if business prospects are positive ($\delta_i = \nu$).

3. The ifo firm panel data

In order to undertake an empirical investigation of the impact of asymmetric information on credit markets several approaches are possible. In principle, a hypothesis derived from the micromodel can be tested in an aggregate model of the loan

market (Winker (1996)) concentrating on rigidities of the price mechanism on this market.[8]

However, to test directly for the impact of firm specific characteristics on their rationing probability, as well as the impact of financing deficits on their investment decisions and innovation expenditures, microdata have distinct advantages if they cover the relevant variables.

The data source used here for the empirical investigation of determinants and effects of financing constraints is a unique panel of micro data from West German manufacturing firms. The data combine observations of the monthly business survey, the annual investment survey and the annual survey on innovation activities of the ifo institute, Munich (cf. Schneeweis and Smolny (1996) for a detailed description of the dataset). Annual data for the time period 1982–1991 are available for 1919 firms and plants in manufacturing, which participated at least once in all three surveys, and still existed in 1984.

Missing observations reduce the number of available observations to 6855 out of the maximum possible number of 19190. There are three main sources for missing observations: firms leaving the panel, new firms entering the panel, and unwillingness of the firms to answer to all questions (or even to fill in the questionnaire) for some waves. The possibly most serious problem of attrition was tested for by including some attrition dummies in the estimated equations without finding major effects. However, the sparse structure of the data set limits the usefulness of some panel estimators, such as fixed effects.

The most prominent feature of the ifo firm panel data for the purpose at hand is that it contains direct information on financing deficits. In the survey on innovation activities firms are asked whether they faced impediments to innovation activities. Besides other principal impediments, such as too low an expected return, not enough qualified employees or unwillingness of employees and management, firms can select "missing external funds" (*MEF*) and "missing internal funds" (*MIF*). Thus, firms themselves indicate whether they face financing constraints. Therefore, avoiding the reliance on proxies, such as cash flow, which might be less suitable (cf. Faroque and Ton-That (1995)).

As the question on financial constraints appears only in the context of innovative activities, the observations, for those firms and time periods when no innovation activities were required for the current period, had to be excluded from the sample. Consequently, the variables measuring financing constraints comprise the decision to undertake projects requiring some funding, and the information whether this funding was available or not. A possibly resulting selection bias was tested in a bivariate probit framework, modeling the decision to undertake innovation activities on available data from the other business surveys. As the qualitative results did not change (cf. Winker, 1996, p. 101), and as innovative activities and investment decisions are closely linked, it seems admissible to use this approximation.

Table I gives the percentage of firms characterising themselves as financing constrained, either by missing external or internal funds. The last column gives the percentage of firms facing either constraint.

The differentiation between missing external or internal funds seems questionable for small firms in particular; quite often, firms are denied a loan because of missing equity. Whether a firm will describe this state as rationing, by missing internal funds, rather than by missing external funds, is not clear. Hence, the empirical analysis is based on both rationing variables as well as on the variable indicating either missing external or internal funds (*MF*). Finally, the marked change in the level of all three financing constraints indicators in 1991 has to be attributed to a change in the questionnaire, now allowing firms to differentiate between modest and strong impediments. As both cate-

TABLE I
Impediments to innovations 1982–1991

Year	Missing external funds	Missing internal funds	Missing funds
1982	7.89%	36.09%	36.47%
1983	5.56%	29.12%	29.12%
1984	5.75%	29.61%	29.78%
1985	5.58%	28.89%	29.26%
1986	4.78%	25.67%	26.57%
1987	4.64%	22.41%	22.87%
1988	3.42%	20.09%	20.54%
1989	3.56%	17.15%	17.31%
1990	3.06%	17.35%	17.69%
1991	13.00%	29.20%	30.00%

gories are summarized, the change in level results, in a large extent, from a different threshold when financing constraints are realized. In the estimation, this level effect is catched up by the year dummy for 1991. Furthermore, the results are robust against leaving out the observations for 1991.

In order to test the hypotheses derived in the previous section, the explanatory variables of central interest are the age and business prospects of the firm. Unfortunately, the age of the firms is not contained in the data set. Instead, firm size is measured by the number of employees (*FE*). Given the industrial sector, which is controlled for by including sectoral dummies in the estimated equations, *FE* is a reasonably good proxy for the age of the firm, in the sense that firms starting up business are comparably small (cf. Evans, 1987; Dunne, Roberts and Samuelson, 1989; Audretsch, 1991, 1997; and Wagner, 1994).[9] However, it does not solely measure the direct impact of age described in the previous section, but may also comprise information on equity base, direct access to capital market or its legal form (cf. Gertler and Gilchrist, 1994, pp. 313f), influencing the rationing probability in the same direction as the simple age effect. Furthermore, effects of diversification may be covered. For some specifications, a diversification dummy (*DIV*) is added, which equals one for multi-product firms, and zero otherwise.

While the age of the firm has to be proxied, a distinct advantage of the ifo firm panel is the fact that it includes estimates of the current business situation as well as expectations about the future development. While banks may know whether the current business situation of the firm is good (B^+), medium (B^0) or bad (B^-), it is probably less well informed about the expectations at the firm level.[10] In particular, firms with negative business prospects ($B\searrow$) have no incentives to report it to their banks.[11] Consequently, positive business prospects ($B\nearrow$) must also be considered as private information to the firm. Both variables are used to model the impact of asymmetric information along the lines depicted in subsection 2.4. Ceteris paribus, the risk of facing financing constraints should be positively correlated with positive business expectations ($B\nearrow$) at the firm level, while positive expectations at the sectoral level ($\overline{B\nearrow}$) are more likely to be observable by banks and, therefore, lead to increased loan supply and less rationing.

The impact of financing constraints is analyzed through changes in innovation and investment expenditures. In order to control for the firm size such expenditure data have to be normalized. The preferable normalization by value added or capital stock is not possible as these variables are not contained in the data set. Therefore, a normalization by sales had to be used. The share of expenditures on innovation activities in sales is denoted by *INQ*, while *IQ* denotes the share of investment expenditures.

In addition to the dummies for financing deficits, the degree of capacity utilization (Q_{-1}^{100}) is used to control for cyclical effects at the firm level. In particular, cash flow is assumed to depend on capacity utilization in the previous period.

Finally, all specifications include time dummies to control for macroeconomic conditions and – if not stated otherwise – sectoral dummies to control for sector specific effects. Table II provides means and standard deviations of the variables used for estimation.

4. Empirical specification

Based on the arguments given in section 2, the following model of the indicator variables for financial constraints (*MF*) is obtained

$$MF = f(SI, BP, CB, X), \tag{7}$$

where *SI* is a measure of firm size reflected by log *FE* or size dummies $SK_1, \ldots, SK_4$ for firms with less than 50, 50–199, 200–999 and more than 999 employees, respectively; *BP* captures business prospects; *CB* reflects the current business situation; and *X* includes other variables to control for observable characteristics and macroeconomic effects. The firms' industrial sector and a diversification dummy are used in some specifications, while year dummies are always included to mirror macroeconomic influences, such as interest rates, general wage and price trends or general business conditions.

As the information about financing constraints in the data set is qualitative, limited dependent variable models such as Probit estimation are used for the estimation of equation (7).

TABLE II
Descriptive statistics for the used variables

Variable		Scale	$\bar{x}$	σ_x
Miss. external funds	*MEF*	dummy	0.047	
Miss. internal funds	*MIF*	dummy	0.214	
Missing funds	*MF*	dummy	0.218	
Employees in firm	log *FE*	log.	2.494	0.695
< 50 employees	$SK_1 = 1$	dummy	0.121	
50–199 employees	$SK_2 = 1$	dummy	0.275	
200–999 employees	$SK_3 = 1$	dummy	0.384	
Diversification	*DIV*	dummy	0.684	
Good business sit.	B^+	dummy	0.203	
Bad business sit.	B^-	dummy	0.165	
Improving bus. sit.	$B\nearrow$	dummy	0.094	
Worsening bus. sit.	$B\searrow$	dummy	0.114	
Investment ratio	*IQ*	share	0.051	0.066
Innovation ratio	*INQ*	share	0.030	0.052
Capacity utilization	Q_{-1}^{100}	percent	83.162	12.813

The impact of financing constraints on investment behaviour and innovative activities is tested following the approach by Fazzari, Hubbard and Petersen (1988), Hoshi, Kashyap and Scharfstein (1991), Blundell, Bond, Devereux and Schiantarelli (1992), Elston and Albach (1995) among others. In these studies, standard investment functions or models for R&D expenditures are augmented with variables proxying financing constraints, such as firm size, cash flow or access to the capital market. Although the estimation of (7) will show a significant influence of such observable individual characteristics, a large part of the variance remains unexplained.

Therefore, it seems preferable to use a direct approach which is feasible due to the unique information on financing constraints in the ifo firm panel. Then, the risk of biased estimates of the impact of financing deficits on real activity due to bad proxies (cf. Faroque and Ton-That, 1995, p. 312) can be avoided.

The estimation equation for the ratio of innovation expenditures to sales (*INQ*) is specified as[12]

$$INQ = \alpha_0 + \alpha_1 MF + \alpha_2 X^{ie} + \epsilon, \tag{8}$$

where X^{ie} captures other explanatory variables such as firm size, business prospects, sectoral dummies, mean of innovation ratio of the sector in a given year etc. As the variable *INQ* is left-censored by zero, a Tobit model is estimated in contrast to most of the cited studies using OLS estimates.

The investment ratio (*IQ*) is analyzed based on a dynamic model of the firm allowing for effects of rationing on goods and labour markets (cf. Smolny, 1993). The resulting equation to be estimated is given by

$$IQ = \beta_0 + \beta_1 MF + (\beta_2 + \beta_3 MF) Q_{-1}^{100} + \beta_4 X^{iv} + \epsilon, \tag{9}$$

where X^{iv}, again, captures other control variables. Apart from a level effect (β_1), as for the expenditures for innovative activities, the model allows for the effect of financing constraints to depend on the degree of capacity utilization as expressed by β_3. For example, firms facing a low degree of capacity utilization may react more to financing constraints, both for a cash flow effect and for lower expected future demand.[13] Again, the estimation is performed as Tobit model due to the left censoring of *IQ*.

The existence of adjustment costs may justify including lagged observations of the endogenous variables in the estimation equations. However, for innovation expenditures in particular, the sparse structure of the panel considerably reduces the number of available observations in this case. Nevertheless, some results of this dynamic specification are also reported.

5. Results of estimations

5.1. *Causes of financing constraints*

Some results of the estimation of equation (7) are shown in Table III. Except for the random effects specification (3), individual heterogeneity is controlled for only by the inclusion of sectoral and time specific means calculated for the exogeneous variables without the respective firm. The inclusion of fixed effects does not seem to be very useful in this context, due to the number of consecutive observations per firm being small as well as the variance of the financing constraints dummies for a single firm over time.

TABLE III
Financing constraints and firm size

	Dependent variable: *MP*			
	Pooled probit			Random effects
	(1)		(2)	(3)
Constant	0.418		–1.485	–2.122
	(1.34)		(–5.49)	(–3.26)
log *FE*	–0.551	SK_1	0.670	0.704
	(–15.71)		(10.43)	(5.20)
		SK_2	0.379	0.313
			(7.55)	(3.16)
		SK_3	0.008	–0.05
			(0.17)	(–0.62)
B^+	–0.286		–0.297	–0.368
	(–5.22)		(–5.97)	(–4.62)
B^-	0.185		0.252	0.270
	(3.45)		(5.22)	(3.55)
$B\nearrow$	0.256		0.194	0.198
	(3.81)		(3.20)	(2.08)
$\overline{B\nearrow}$	–0.557		–0.376	–0.606
	(–1.08)		(–0.80)	(–0.90)
$B\searrow$	0.001		0.045	0.123
	(0.13)		(0.79)	(1.40)
$\overline{B\searrow}$	–0.730		–0.480	–0.645
	(–1.82)		(–1.37)	(–1.29)
ρ	–		–	1.452
				(29.556)
Lik. ratio χ^2	651.999		566.213	2729.701
d.f.	41		43	46

FE = firm employment.
SK = employment size classes.
B = current and expected business situation.
$\overline{XX}$ = sectoral and time specific mean of variable *XX* without firm.
All specifications include dummies for industrial sector and time.

The dependent variable *MF* is a dummy with value 1 if the firm faces a situation of financing constraints for the current period. Therefore, a positive coefficient for an explanatory variable indicates ceteris paribus an increased risk of facing financing constraints. The *t*-statistics for the estimated coefficients are included in parentheses.

All three specifications in Table IV show a highly significant negative effect of firm size as a proxy for the age of firms. The larger a firm became, the lower is ceteris paribus the risk of facing financial limitations. This confirms the theoretical result and the approach used in the literature to proxy financing constraints by firm size.

Current business situation shows the expected effect as good current businesses (B^+) reduce the rationing risk, whereas bad current businesses (B^-) tend to increase it. The reference category is defined by the firms considering their business situation as average. Current business situation can be observed by banks and is used as a screening variable. Firms with different current business situations will belong to different segments of the loan market. Consequently, the sectoral and time specific mean of current business situation should not have a relevant influence. This is confirmed by (not reported) specifications including these means.

An inverse effect is found for the future business prospects representing asymmetric information effects. If a firm expects an improvement of its business situation ($B\nearrow$) it has to face a higher risk of rationing compared to the reference category of firms expecting no change in their business prospects. This effect is rather strong compared to the contrary effect of improved business expectations for the whole sector. Only if about half of the sector expects improving businesses, the net effect for a single firm with $B\nearrow = 1$ will be zero. On the other hand, if a worsening is expected for the whole sector, the financing limitations for a single firm become less binding ceteris paribus, whereas a worsening of own business prospects has no significant effect. This finding confirms the theoretical analysis of section 2.4 and supports the importance of asym-

TABLE IV
Effects of financing constraints on innovation expenditures

	Dependent variable: *INQ* Pooled tobit			
	(1)	(2)	(3)	(4)
Constant	0.026 (6.73)	0.020 (1.41)	0.026 (1.83)	0.014 (0.92)
MF	–0.016 (–6.72)	–0.037 (–5.91)	–0.011 (–4.49)	–0.007 (–2.33)
$\overline{INQ}$	0.683 (11.81)	–0.260 (–2.29)	–0.255 (–2.26)	–0.006 (–0.42)
INQ_{-1}	–	–	–	0.410 (20.49)
Sectoral dummies	without	with	with	with
Firm size dummies	without	without	with	with
Changing business prospect dummies	without	without	with	with
ρ	0.064 (88.19)	0.063 (88.11)	0.063 (88.12)	0.055 (68.68)
Log-likelihood	4842.5	4912.2	4952.3	3321.8

$\underline{MF}$ = dummy for financing constraints.
$\overline{XX}$ = sectoral and time specific mean of variable *XX* without firm.
t-statistics in parenthesis.

metric information about future developments as source of financing constraints.

In specification (3) the potential problem of unobserved individual heterogeneity omnipresent in panel data econometrics was tackled by the estimation of a random effects model (cf. Butler and Moffitt, 1982). The estimated coefficient ρ is large. The Durbin-Wu-Hausman specification test (cf. Davidson and MacKinnon, 1993, pp. 389ff) indicates significance at the 1% level. The increase in some of the parameter estimates is contributed to the fact that the a priori standard deviation of the residuals is not normalized to 1 anymore. Instead, the standard deviation is given by $\sqrt{\rho^2 + 1} \approx 1.77$. However, the qualitative results are not changed.

In order to assess the robustness of the results, some specification tests with respect to the possible heteroscedasticity of the error terms, non random attrition and non random selection were performed (cf. Winker, 1996), p. 99f.). Although the hypothesis of heteroscedasticity with respect to some of the sector dummies and a partially non random selection could not be rejected, the estimation results of models correcting for these effects did not differ substantially from the ones presented in Table IV.

5.2. *Effects of financing constraints*

Table V summarizes the results of the estimation of equation (8). Again, all specifications include time dummies to capture macroeconomic trends. In contrast to most of the above cited studies, a pooled tobit estimator is used to take account of the left-censored data. In (1) a parsimonious specification of equation (8) is used, whereas (2) and (3) in addition include some of the explanatory variables for the financing constraints, such as firm size dummies and dummies for changing business prospects, which might also have a direct impact on innovation expenditures. Finally, specification (4) includes the lagged endogenous variable, reducing the number of available observations from 4623 to 2743 due to the sparse structure of the data set.

For all specifications, a highly significant negative influence of financing constraints on innovation expenditures is found. This effect remains significant even after including some

TABLE V
Effects of financing constraints on investment

	Dependent variable: *IQ* Pooled tobit			
	(1)	(2)	(3)	(4)
Constant	–0.010	–0.001	0.016	0.009
	(–1.10)	(–0.03)	(0.96)	(0.53)
MF	–0.054	–0.055	–0.055	–0.044
	(–3.75)	(–3.82)	(–3.81)	(–3.08)
$Q_{-1}^{100}/100$	0.035	0.041	0.024	0.018
	(3.94)	(4.64)	(2.55)	(1.89)
$Q_{-1}^{100}/100 \times MF$	0.061	0.062	0.065	0.053
	(3.50)	(3.56)	(3.73)	(3.04)
$\overline{IQ}$	0.782	0.001	–0.017	–0.066
	(14.89)	(0.01)	(–0.166)	(–0.65)
IQ_{-1}	–	–	–	0.321
				(19.49)
Sectoral dummies	without	with	with	with
Firm size dummies	without	without	with	with
Changing business prospect dummies	without	without	with	with
ρ	0.071	0.070	0.070	0.068
	(105.21)	(105.20)	(105.20)	(102.68)
Log-likelihood	6723.1	6821.1	6844.5	6651.4

$\overline{MF}$ = dummy for financing constraints.
$\overline{XX}$ = sectoral and time specific mean without firm.
t-statistics in parenthesis.

explanatory variables for the financing constraints dummy. Therefore, it is not surprising that the effects on innovation expenditures found using the available direct information on financing constraints is larger than those reported in the literature using indirect approaches. In fact, the mean ratio of innovation expenditures to sales amounts to 3% in the whole sample and is reduced to less than 2% for the constrained firms.[15]

The sectoral and time specific mean of the dependent variable calculated without the value of the respective firm (*INQ*) loses importance as soon as sectoral dummies and other individual characteristics of the firm are added. Hence, it might be concluded that *INQ* mainly reflects heterogeneity at the sectoral level.

The results of the dynamic specification (4) are not directly comparable to the other results due to the smaller sample. However, the order of magnitude of a permanent financing constraints effect is similar.

Table V summarizes the results of the estimation of equation (9) for the investment to sales ratio, as no more preferable scale variables, such as capital stock are available in the data set. The cyclical component of sales is partially captured by the capacity utilization variables. Again, all specifications include time dummies to capture macroeconomic trends including wages and prices. In (1) a parsimonious specification of equation (9) is used, including variables for the degree of capacity utilization and the sectoral and time specific mean of the endogenous variable. The variable Q_{-1}^{100} is used with one lag in order to reduce a possible simultaneity bias. Specifications (2) and (3), in addition, include some of the explanatory variables for the financing constraints, while (4) again, presents a simple dynamic specification.[15]

Again, a highly significant negative impact of financing constraints is found on investment expenditures. Hence, it may be concluded that the possibly subjective assessment of financial constraints at the firm level is, in fact, closely

connected to their real decisions; in other words, financial constraints do matter!

In contrast to the estimation results for the innovation expenditures, a significant effect of the degree of capacity utilization is found for the investment to sales ratio. The influence becomes smaller if firm size dummies and dummies for changing business prospects are included ((3) and (4)). The effect of capacity utilization differs between rationed and non rationed firms. Both the financing constraint dummy itself, and the interaction term with the utilization variables are significant in all specifications.

While the dummy *MF* has a negative impact on investment, the interaction with Q_{-1}^{100} shows a positive sign, indicating a higher sensitivity of investment with regard to the degree of capacity utilization for rationed firms. This might be explained by the fact that the rationing dummy mirrors the existence, but not the extent of financing constraints. Thus, firms with a ceteris paribus higher degree of capacity utilization in the last period might face a smaller financing deficit due to an increased cash flow (this effect is used by Fazzari, Hubbard and Petersen (1988) to estimate the impact of financing constraints on investment).

The overall effect of financing constraints is not uniform. While firms with a low degree of capacity utilization reduce their investment expenditures heavily when facing financing constraints, a slight increase can be found for firms with near to full utilization of capacities.

Again, the significant influence of the financing constraints dummy and the interaction terms with the degree of capacity utilization persist, if, instead of the general financing constraints dummy, a dummy for missing internal or missing external funds is used. The same holds true for the dynamic specification.

6. Conclusion

A microeconometric method was used in this paper to assess the relevance and impact of credit rationing at the firm level. The main advantage of this approach is that rationing of individual firms can be explained by individual characteristics of the firms including asymmetric information.

The framework of the Stiglitz and Weiss model was used to demonstrate the impact of age, size and business relations of firms on the probability of being rationed on the credit market. Furthermore, the microdata of the ifo institute allowed for constructing a variable closely correlated with the informational asymmetry between the firm and its possible creditors.

The empirical results confirm the impact of these variables. Ceteris paribus, older firms face a lower risk of being rationed on the credit market, whereas asymmetric information due to improving business expectations will increase this risk.

The answers of the firms on the question about impediments to innovation allow the conclusion that credit rationing is a relevant phenomenon for the German credit market. Furthermore, the impact of financial limitations on the activities of firms leads to the deduction that rationing on credit markets might be important for a deeper understanding of the monetary transmission mechanism.

It will be the subject of further research to assess the quantitative importance of credit rationing on an aggregate level (cf. Winker, 1996).

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Appendix

A. *Proof of Proposition 1*

Let $\tilde{f}$ and $\tilde{f}_n$ be given by

$$\tilde{f}(p) = \frac{1}{F(p^*)} f(p) \quad \text{and} \quad \tilde{f}_n(p) = \frac{1}{F_n(p^*)\kappa_n} p^n f(p)$$

on $[0, p^*]$, where $\kappa_n \equiv \int_0^1 f(p)p^n \mathrm{d}p$ for $n \in \mathbb{N}$. $\tilde{f}$ and $\tilde{f}_n$ are densities, i.e.

$$\int_0^{p^*} \tilde{f}(p)\mathrm{d}p = \int_0^{p^*} \tilde{f}_n(p)\mathrm{d}p = 1. \quad (10)$$

Furthermore, $\tilde{f}(0) = \tilde{f}_n(0) = 0$ by definition. Setting $C_n = F(p^*)/(F_n(p^*)\kappa_n)$ and $\epsilon = \min\{\sqrt[n]{(1/C_n)}, p^*\}$ one obtains

$$\tilde{f}_n(p) < \tilde{f}(p) \text{ for all } p \in [0, \epsilon[. \quad (11)$$

From equation (10) it follows the existence of $p_0 \in]0, p^*[$ with $\tilde{f}_n(p) = \tilde{f}(p)$; hence $C_n p_0^n f(p_0) = f(p_0)$ and finally

$$\tilde{f}_n(p) > \tilde{f}(p) \text{ for all } p \in]p_0, p^*[.$$

In particular, p_0 is unique, and again with equation (10) it follows

$$-\int_0^{p_0} (\tilde{f}_n(p) - \tilde{f}_n(p))\mathrm{d}p = \int_{p_0}^{p^*} (\tilde{f}_n(p) - \tilde{f}(p))\mathrm{d}p.$$

Due to the monotony of the integral operator one obtains

$$-\int_0^{p_0} p(\tilde{f}_n(p) - \tilde{f}_n(p))\mathrm{d}p < \int_{p_0}^{p^*} p(\tilde{f}_n(p) - \tilde{f}(p))\mathrm{d}p,$$

and with $(1 + r)B > R^f$ the proposition $E_n(\pi_b) > E(\pi_n)$ results for $n \geq 1$ and $p^* > 0$.

B. *Derivation of results for section 2.4*

In section 2.4 an additional stochastic element was introduced capturing firm business expectations. Given $\delta_i \in \{-\nu, 0, \nu\}$ the expected net return of firm i becomes according to equation (1)

$$\begin{aligned} E(\pi_i) &= p_i[(1 + \delta_i)R_i^s - (1 + r)B] \\ &= p_i[R_i^s - (1 + r)B] + \delta_i p_i R_i^s. \end{aligned}$$

Using $R = p_i R_i^s + (1 + p_i)R^f$ equation (1) now reads

$$E(\pi_i) = R - R^f - p^i[(1 + r)B - R^f) + \delta_i p_i R_i^s. \quad (12)$$

Obviously, $E(\pi_i)$ depends positively on δ_i. For $\delta_i = \nu$ the expected return rises. Consequently, the cut-off probability implicitly defined by

$$E(\pi_i) \geq (1 + \rho)W$$

will also rise. Ceteris paribus, the marginal success probability will be larger for firms with $\delta_i = \nu$. Just the opposite holds for $\delta_i = -\nu$. If the distribution of δ_i is independent of the distribution of π_i, the share of firms with $\delta_i = \nu$ demanding a loan will be larger than in the whole group of firms with otherwise identical characteristica.

The marginal success probability is given if (12) holds with equality. Let p^* denote the marginal success probability for firms with $\delta_i = 0$. Then, the change Δp^*due to $\delta_i \neq 0$ is calculated according to

$$\begin{aligned} &R - R^f - (p^* + \Delta p_i)\,[(1 + r)B - R^f] + \delta(p^* + \Delta p^*)R_i^s \\ &\quad = (1 + \rho)W \\ &\Leftrightarrow \Delta p^*[(1 + r)B - R^f] = \delta(p^* + \Delta p^*)R_\delta^s \end{aligned} \quad (13)$$

where R_i^s denotes the normal (i.e. for $\delta = 0$) return to a successful project with success probability equal to $p^* + \Delta p^*$. Using again $R = (p^* + \Delta p^*)R_\delta^s + ([1 - (p^* + \Delta p^*)R^f$, one obtains

$$R_\delta^s = \frac{R - [1 - (p^* + \Delta p^*)]R^f}{p^* + \Delta p^*}.$$

Now, equation (13) becomes

$$\begin{aligned} \Delta p^*[(1 + r)B - R^f] &= \delta\{R - [1 - p^* + \Delta p^*)]R^f\} \\ &= \delta[R - (1 - p^*)R^f] + \Delta p^*\delta R^f \\ \Leftrightarrow \Delta p^*\underbrace{[(1 + r)B - (1 + \delta)R^f]}_{>0} &= \underbrace{\delta[R - (1 - p^*)R^f]}_{>0}. \end{aligned}$$

Consequently, $\mathrm{sgn}(\Delta p^*) = \mathrm{sgn}(\delta)$, for $\delta = \nu > 0$ the marginal success probability will increase, whereas for firms with $\delta = -\nu < 0$ it will decrease. Furthermore, comparing Δp^* for $\delta = \nu$ and $\delta = -\nu$ one finds

$$\begin{aligned} \Delta p_\nu^* &= \frac{\nu[R - (1 - p^*)R^f]}{(1 + r)B - (1 + \nu)R^f} \\ &> \frac{\nu[R - (1 - p^*)R^f]}{(1 + r)B - (1 + \nu)R^f} = |\Delta p_{-\nu}^*|. \end{aligned}$$

This result indicates that the quality of the risk pool of loan demanding firms will improve if the additional stochastic element is introduced. Nevertheless, rationing might still occur and is concentrated on good business prospect firms as compared to their share in the whole sample.

Notes

[1] Jaffee and Stiglitz (1990) offer a survey of the theoretical literature on credit rationing based on asymmetric information.

[2] For example, a survey of the Deutsche Ausgleichsbank (1995) indicates that of the East German firms newly founded in 1990, almost one half (49.2%) reported financing deficits in 1994.

[3] Cf. Gertler (1988, 1992) and Jaffee and Stiglitz (1990). Vitols (1998) and Deeg (1998) describe the specific features of the German banking system.

[4] Cf. e.g. Oliner and Rudebusch (1992) and the literature cited in Kaplan and Zingales (1997) and Audretsch and Elston (1997).

[5] The ZEW innovation panel described in Egeln, Licht and Steil (1997) includes a similar variable, but so far covers only a short time span.

[6] Diamond (1984) and Williamson (1986) show that standard loan contracts are the optimal way to raise funds if monitoring is costly.

[7] As for the standard Stiglitz and Weiss model it is assumed that the return to a successful project is always large enough to pay back debt plus interest while the return to a failed project does not cover the liability towards the bank.

[8] Examples of applications to the German credit market are Kugler (1987) and Winker (1998).

[9] Using a dataset containing information both on firm size and age, Egeln, Licht and Steil (1997) find a highly negative impact of both variables on the risk of facing financing constraints.

[10] The questionnaire asks for a judgment on current production and for business prospects during the next half-year above purely seasonal effects.

[11] Fortunately, the anonymous data of the ifo panel are not flawed by these incentives, as the expectations expressed in the questionnaire show a high positive correlation over time with their ex post realizations.

[12] For a related specification and some theoretical background see, e.g., Himmelberg and Petersen (1994), pp. 44ff.

[13] As the planing horizon for innovation expenditures is longer than for investment, the capacity utilization variables are omitted from specification (9). In some preliminary tests Q_{-1}^{100} exhibited now significant impact on *IQ*.

[14] The results do not differ essentially if the general financing constraints dummy is replaced by dummies for constraints by internal and external finance, respectively.

[15] The sample size is reduced moderately from 5651 to 5379, as the observations in the investment survey are more dense in time.

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