

# More money, more innovation?

## Innovation Capacity and Financing Constraints for Innovation

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**Abstract:** This study presents an approach to identify financing constraints for innovation. Firms were offered a hypothetical payment and were asked to choose between alternatives of use. We attribute constraints for innovation not only to lacking financing, but also to firms' innovation capacity. Econometric results show that financial constraints do not depend on the availability of internal funds per se, but are driven by innovation capacity. We find firms with high innovation capacity but low financial resources to be most likely face constraints. Yet, we also observe constraints for financially sound firms that may have to put ideas on the shelf.

**Keywords:** Innovation, Financing Constraints, Ordered Probit Models with Selection, Multivariate Probit Models

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# 1 Introduction

After the key assumption underlying standard neoclassical models on perfect capital markets were challenged in the 1970's and 1980's, the questions of financial constraints for investments gained importance. In particular, economic theory suggested that financing constraints may occur if one of the parties involved knows considerably more about the investment than the other. Such information asymmetries may be especially relevant for investments in innovation projects as such investments typically are characterized by a high degree of complexity and specificity increasing the difficulty for outsiders to judge the projects' potential value. Moreover, firms may be reluctant to reveal details of the projects to potential investors. Hence, financing innovation externally may be more costly compared to financing of capital investment (Meyer & Kuh 1957, Stiglitz & Weiss 1981, Anton & Yao 2002). Internal sources of financing, therefore, are crucial for the implementation of innovation projects (Leland & Pyle 1977, Bhattacharya & Ritter 1983, Hall 1990, Hall 1992, Himmelberg & Peterson 1994). However, internal funds are not inexhaustible either. Cash flow is naturally limited and raising new equity may be costly and often unwanted (Carpenter & Petersen 2002).

Financing constraints, however, may not affect all firms to the same extent. This paper addresses the questions of identifying potentially constrained firms. The answer to this question is particularly relevant for policy makers to design effective policy schemes as financing constraints lead to suboptimal level of investment in innovation.

In contrast to previous empirical studies that tested the presence of financing constraints indirectly by the sensitivity of R&D-investment to changes in internal funds, we take a direct approach. It is based on the idea of an ideal test for identifying the effects of liquidity constraints on investment in innovation as proposed by Hall (2008). She suggests that 'the ideal experiment for identifying the effects of liquidity constraints on investment is to give firms additional cash exogenously, and observe whether they pass it on to shareholders or use it for investment and/or R&D. [...] If they choose the second [alternative], then the firm must have had some unex-

exploited investment opportunities that were not profitable using more costly external finance’.

This study contributes to the literature in following three main aspects. First, we employ a direct indicator derived from survey information. Firms that were asked to imagine that they receive additional cash exogenously and to indicate how they would spend it. Thus, we directly observe whether firms choose to invest either all or part of the cash in innovation projects. Second, we account for the firm’s choice between alternatives of use for the money in our econometric analysis. Such an approach is crucial as investing in innovation projects competes with other purposes of firms’ available funds. Third, we introduce the concept of innovation capacity and how it affects financing constraints for innovation. To the best of our knowledge, this fundamental aspect of the firms’ innovation process has attracted little attention in this strand of the literature so far.

The results from our econometric analysis show that financial constraints do not depend on the availability of internal funds per se, but are driven by innovation capacity by increasing resource requirements. That is, we find that firms with high innovation capacity but low financial resources turn out most likely to be constrained. Yet, we also observe constraints for financially sound firms that may have to put some of their ideas on the shelf. Firms with low innovation capacity choose other options. Moreover, the multidimensional analysis taking all options for usage of the additional money into account shows that firms with a bad credit rating would primarily repay debt.

This article reviews previous literature in section 2. Section 3 describes the theoretical background, the role innovation capacity for financing constraints and conceptual framework of our study. The data and econometric model specifications as well the results from the different models are presented in section 4 and 5, respectively. Section 6 concludes.

## 2 Financing Constraints for Innovation: What do we know?

### 2.1 Theoretical Arguments for Financing Constraints

In principle, there are two sources for financing innovation projects. External sources such as bank loans or other debt contracts and internal sources, that is retained profits or (new) equity. Firms decide upon their optimal levels of investments while choosing their capital structure in such a way as to minimize long run cost of capital. Only in a neo-classical world with frictionless markets source of financing would not matter. In a seminal article Modigliani & Miller (1958) show that in markets where there are no taxes, no bankruptcy costs and no asymmetric information investments decisions are indifferent to capital structure.

However, starting with the work of Arrow (1962) and Nelson (1959) numerous articles have elaborated on reasons illustrating why the source of financing does matter and in particular matters for investments in the creation of knowledge. If capital markets are imperfect and information asymmetries influence lending and investment decisions, the cost of different kinds of capital may vary by type of investment (Meyer & Kuh 1957, Leland & Pyle 1977, Myers & Majluf 1984).

Investment in innovation compared to other types of investments is characterized by a high degree of asymmetric information between the parties involved. Complexity and specificity of innovation projects make it difficult for outsiders to judge their potential value. Moreover, firms may be reluctant to reveal details of the projects to potential investors for competition reasons (Stiglitz & Weiss 1981, Greenwald, Stiglitz & Weiss 1984, Bhattacharya & Ritter 1983, Anton & Yao 2002). Lenders or investors may demand a 'premium' on their required rate of return in the sense of Akerlof (1970). If no pursuant rate of return can be appropriated, investors may ration their investment or even refrain from investing at all (Stiglitz 1985).

Moreover, moral hazard problems between the management of the firm and outsiders, such as investors or lenders, as well as information asymmetries between management and owners may impact investment in innovation projects and, hence

financing conditions (Jensen & Meckling 1976, Grossman & Hart 1982, Czarnitzki & Kraft 2004b).

Besides information asymmetries, the intangibility of the asset that is being created by the investment may make raising funds externally more costly for innovation than for other types of investments. A large fraction of innovation investments, particularly R&D, is sunk and cannot be redeployed (Alderson & Betker 1996). Debt-holders such as banks prefer physical and redeployable assets as security for their loans, since those can be liquidated in case the project fails or bankruptcy. Moreover, serving debt requires a stable cash flow which makes financing of innovation projects by external sources more difficult, since most of these projects do not immediately lead to success. In addition, serving debt reduces cash flow for future investments (Hall 1990, Hall 2002).

There is a whole branch of theoretical and empirical literature illustrating that firms indeed first and foremost use internal funds to finance innovation projects (as compared to debt) indicating a gap in the cost of capital (Leland & Pyle 1977, Bhattacharya & Ritter 1983, Hall 1990, Hall 1992, Himmelberg & Peterson 1994, Bougheas, Görg & Strobl 2003, Czarnitzki & Hottenrott 2009). Consequently, the extent to which financial constraints are binding depends on the firms' ability to raise external or internal funds under the conditions of imperfect capital markets.

## 2.2 Empirical Evidence

Empirical studies on financing constraints for innovation, more precisely on R&D as an important input to the firms' innovation process have been studied since the late 1980's. The issue of measuring financial constraints represents a main challenge in empirical studies.

Since the seminal study of Fazzari, Hubbard & Petersen (1988) econometric studies have tried to detect financial constraints by analyzing investments' sensitivities to changes in available financial resources, most often cash-flow. This methodology has subsequently been applied to investments in research and development as such investments constitute an important share of total innovation investments. The conjecture for investment in R&D was derived accordingly: the more sensitive firms'

R&D investment to cash flow the more binding are financial constraints. Excess sensitivities were regarded as indirectly reflecting firms' (lack of access) to the credit market.

Theoretical literature states that financial constraints depend on asymmetric information, moral hazard in borrower-lender relationships, intra-firms organizational structures and other institutional factors. This implies that financing constraints may depend on certain firm and project characteristics. Thus, in order to observe more than an average effect over the entire range of different firms when trying to detect financing constraints, researchers usually split their sample or focus on a particular group of firms a priori. That is firms are grouped into supposedly more and less constrained firms. The latter were expected to be able to raise funds for any investment. For those firms, investment spending should not be sensitive to the availability of internal funds. The former group of potentially constrained firms is expected to show a positive relationship between investment and the availability of financial resources that reveal the existence of liquidity constraints.

Factors impacting financial constraints for R&D frequently investigated in the literature are firms' size in terms of number of employees or assets or firms' age (Himmelberg & Peterson 1994, Petersen & Rajan 1995, Berger & Udell 2002, Czarnitzki 2006, Czarnitzki & Hottenrott 2009), governance structures (Chung & Wright 1998, Czarnitzki & Kraft 2004a), industry patterns (Hall 1992, Bloch 2005) as well as financial market regimes (Bhagat & Welch 1995, Hall, Mairesse, Branstetter & Crepon 1999, Mulkay, Hall & Mairesse 2001, Bond, Harhoff & Van Reenen 2006).

Empirical studies - primarily focusing on manufacturing industries - however, have not always provided unambiguous results. Hall (1992), Himmelberg & Peterson (1994) and find a positive relationship between R&D activity and cash flow for US firms. Mulkay et al. (2001) show that cash flow seems to be more important in the US than in France for any type of investment. Bond et al. (2006) find that for UK firms, cash flow determines whether a firm does R&D, but not how much. They argue that this may indicate that R&D performing firms are a self-selected group of firms that are not constrained. However, they do not find such a relationship for Germany. Harhoff (1998) however, finds such a positive sensitivity to cash flow for

Germany.

Bhagat & Welch (1995) find a negative relationship between debt and R&D activity for US, but not for Japanese firms. For US and UK firms they observe a positive relationship between stock return and R&D activity two years later. Yet, they do not observe any relationship between cash flow and R&D. Bougheas et al. (2003) find similar results for Ireland.

Older and bigger companies seem to be less restricted than younger and smaller firms. This implies that established firms can innovate by building on their previous inventions, e.g. product variation or improvement, while younger firms need to conduct more fundamental R&D which requires more resources and is much more uncertain. Moreover, as Müller & Zimmermann (2006) show, many young firms are restricted in their R&D investment by their equity while older firms are not.

Problems of asymmetric information may be less severe for older firms that have established a long and stable relationship with their bank. Young firms on the other hand have not yet built such a relationship (Petersen & Rajan 1995, Berger & Udell 2002). This may result in financing constraints since exactly those young companies can also not yet rely on internal funds resulting from cash inflow from former products. In addition, bank financing may be limited for innovation projects of young firms because of the overall higher default risk of young companies. This problem may become even more severe as the current financial crises will require banks to conduct an even more detailed risk assessment in the future.

Even though a considerable body of literature exists, the results of these studies first of all often suffer from limitations in data availability. Several of the studies cited above look at either rather large, stock market firms or at small firms only. More severe limitations arise from the conceptual set-up. Kaplan & Zingales (1997) first questioned whether the relationship between cash flow and investment is a sufficient indication of financial constraints (Cleary 1999, Kaplan & Zingales 2000, Fazzari, Hubbard & Petersen 2000, Aydogan 2003).

Especially in the case of large firms, cash flow levels may be determined by accounting and dividend policies to reduce free cash flow in order to mitigate moral hazard

problems (Jensen & Meckling 1976, Jensen 1986, Dhanani 2005). Additionally, the correlation between investment and cash flow may just be a reflection of both of these variables with market prospects or competition.

Finally, firms tend to smooth R&D spending over time (Hall, Griliches & Hausman 1986, Lach & Schankerman 1988). This may also lead to difficulties measuring the impact of changes in availability of financing in one period and investments and subsequent periods.

Recent studies therefore tried to find solutions to this first by investigating firms' access to external funds more directly through the analysis of credit requests (Piga & Atzeni 2007) or standardized credit ratings (Czarnitzki 2006, Binz & Czarnitzki 2008). Second, the increased availability of rich and comprehensive survey data on innovation activities at the firm level has enabled researchers to adopt more direct approaches towards the identification of potentially financially constrained firms. The origination of the Oslo-Manual (OECD/Eurostat 1997) that formulates guidelines for the collection and interpretation of innovation data at the firm level, initiated formation of harmonized innovation surveys. In particular, the Community Innovation Survey (CIS) provides comprehensive firm-level information about all facets of firms' innovation activities.

The survey data allowed researchers asking firms whether lack of financing indeed hampered their innovation projects. For example Savignac (2006) analyzes the impact of financing constraints on the likelihood of established French manufacturing firms to engage in innovation activities. Their French survey data is (like the CIS) based on the guidelines of the Oslo-Manual and provides him with qualitative information about financing constraints that firms may have experienced. Strictly speaking, the survey asked for obstacles to innovation which were related to financing conditions. Savignac (2006) finds that the probability of financing constraints decreases with firm size and depends on the firms' ex-ante financing structure.

Mohnen, Tiwari, Palm & Schim van der Loeff (2007) use CIS2 and CIS3 information to analyze financing conditions for R&D investment in the Netherlands. Besides fi-

nancing related issues they take other hampering factors such as market uncertainty and regulation into account. Thus, they analyze both the impact of perceived financing constraints in R&D-intensity and the likelihood to face financing constraints in the presence of other constraints on R&D activities. They find that firms that report that lack of financing, but no other constraint, are negatively affected on their R&D investments. They also find these constraints to be less binding if firms face other hampering factors.

Canepa & Stoneman (2002) analyze the same type of question as Mohnen et al. (2007) using CIS2 data. They compare inter-country differences in Europe and find a higher perceived importance of financing constraints on innovation for firms' in higher tech sectors and for smaller firms in market-based systems.

Yet, survey-based studies that ask firms whether lacking financing was hampering their innovation activities are also not without limitations either. Most importantly, the interaction of alternative investment opportunities in the firms' decision about their investment are not taken into account. The option of investing in innovation projects competes with other purposes of use for the available funds. That is firms simultaneously determine their level of innovation investments, capital investment, dividend payments, debt payments as well as retentions (Guerard, Bean & Andrews 1987).

### **3 Theoretical Background and Conceptual Framework**

In order to establish a general understanding of financing constraints and the role of innovation capacity in the context of this paper, we draw from a simple supply and demand heuristic following Hubbard (1998), Hall (2002) and Carpenter & Petersen (2002).

We complement this basic setting with introducing the concept of innovation capacity and how it may affect financing constraints for innovation.

Under the assumption of perfect and complete financial markets, borrowing and lending rates are assumed to be equal. The cost of internal funds can be described

as the opportunity costs of investing the money elsewhere, i.e. lending the money to someone else. Thus, firms face the same cost of capital for both internal and external capital (Fisher 1930, Hirshleifer 1958). In such a setting, firms will undertake innovation projects if the expected return of the projects exceeds total implementation costs and financing costs subject to fulfilling all other firm objectives.

Thus, firms will undertake all innovation projects that are expected to be profitable at a given cost of capital.

However, in imperfect capital markets the rate of borrowing is higher than the lending rate. That, is cost of external capital ( $c_{ext}$ ) is higher than cost of internal capital ( $c_{int}$ ). The difference can be expected to be especially high in the case of investment in innovation projects. Uncertainty of returns and intangibility of the research and development activities involved as well as information asymmetries may result in a risk premium added to the borrowing interest rate so that:  $c_{ext} > c_{int}$ .

Moreover, the cost of external capital increase with the total amount borrowed. This yields an individual capital supply function for each firm depending on available internal funds  $IF_i$ <sup>1</sup> and a set of firm characteristics that affect creditworthiness  $CW_i$ , such as for example availability of physical assets that can serve as collateral and capital structure

$$S_i = f(IC_i, IF_i, CW_i).$$

Thus, firms will draw from internal available funds first. Only if expected returns of projects that cannot be financed from internal sources exceed the cost of borrowing, these projects will be carried out as well<sup>2</sup>. Thus, firms for which the optimal number or amount of innovation projects is constrained at a level below what would be invested at capital costs  $c_{int}$  are considered to be financially constrained in their innovation activity.

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<sup>1</sup>It should be noted that these internal funds are not the same as the firms' equity, but those internal funds that are available for innovation investment.

<sup>2</sup>Marginal costs of new equity may be even above marginal costs of borrowing (Carpenter & Petersen 2002)

### 3.1 Innovation Capacity and Financing Demand

In this simple setting, firms face investment opportunities, i.e. innovation projects, that can be ranked by the expected rate of return. Firms choose the optimal investment in innovation projects  $I^*$  as part of their inter-temporal firm value maximization objective. This yields a demand function for capital to finance these projects for each individual firm. We assume the financing demand for innovation to depend on the firm's innovation capacity. Generally speaking, innovation capacity can be understood as the ability to generate new innovation project ideas and is thus reflected in the 'stock of ideas' for potential projects. Thus, the financing demand for innovation of firm  $i$  depends on the expected rate of return of potential projects  $E[r_{inno}]$ , the expected rate of return of alternative investment opportunities  $E[r_{other}]$  and on the firm's innovation capacity ( $IC_i$ ).

$$D_i = f(IC_i, E[r_i^{inno}], E[r_i^{other}])$$

Imagine the case of two firms A and B with B having a higher innovation capacity than A and both face average cost of capital  $c_i$ . We assume that firm B with higher innovation capacity not only invests relatively more in innovation than A such that  $D_B > D_A$ , but that B is more flexible in adjusting its level of investment compared to A. That is, their higher ability to generate ideas leads to a higher elasticity of financing demand:

$$\frac{\partial D(IC_B)}{\partial c_B} > \frac{\partial D(IC_A)}{\partial c_A}.$$

Figure 2 depicts demand for financing of innovation projects  $D_i$  financing supply  $S_i$  for firms  $i = A, B$  with B having a higher innovation capacity than A. In this graph, both firms can finance investment level  $I_A^*$  and  $I_B^*$  fully internally as  $IF_{A,B} > I_{A,B}^*$ . As their innovation potential is entirely exploited, additional cash would have no effect on innovation investment of these firms.

Figure 2, however, illustrates the case in which  $IF_{A,B} < I_{A,B}^*$ . This implies that the number of innovation projects for which the condition that the expected returns



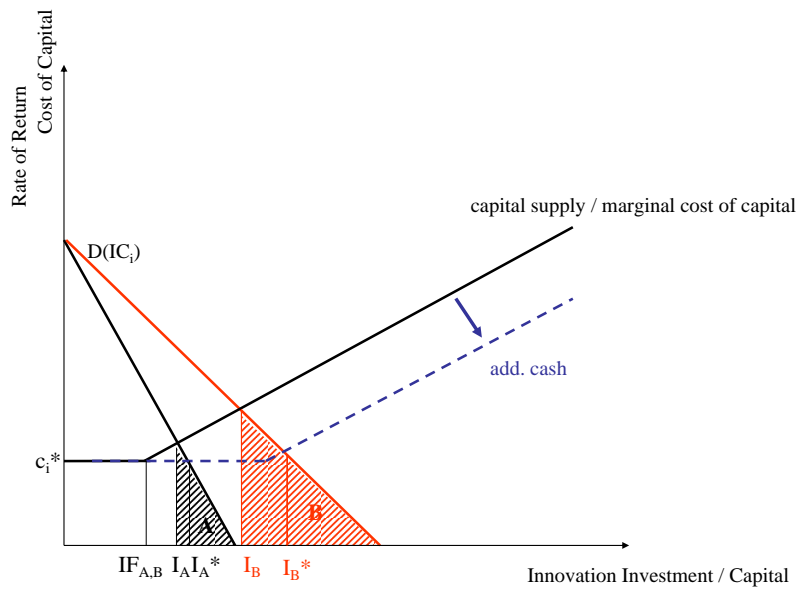


Figure 2: Constrained firms with heterogenous innovation capacity

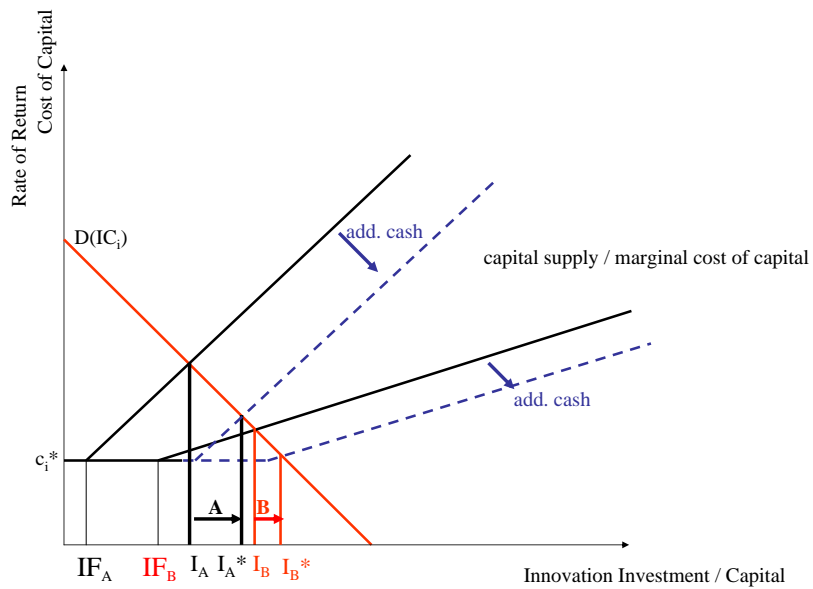


Figure 3: Homogenous innovation capacity, but different available internal funds

same innovation capacity and the same internal funds, the expected expansionary effect from additional cash, is larger for firms that face a larger gap between  $c_{int}$  and  $c_{ext}$  for example due to lower overall collateral value (see figure 4). Finally, we expect a larger effects for if firms that receive the larger cash payment.

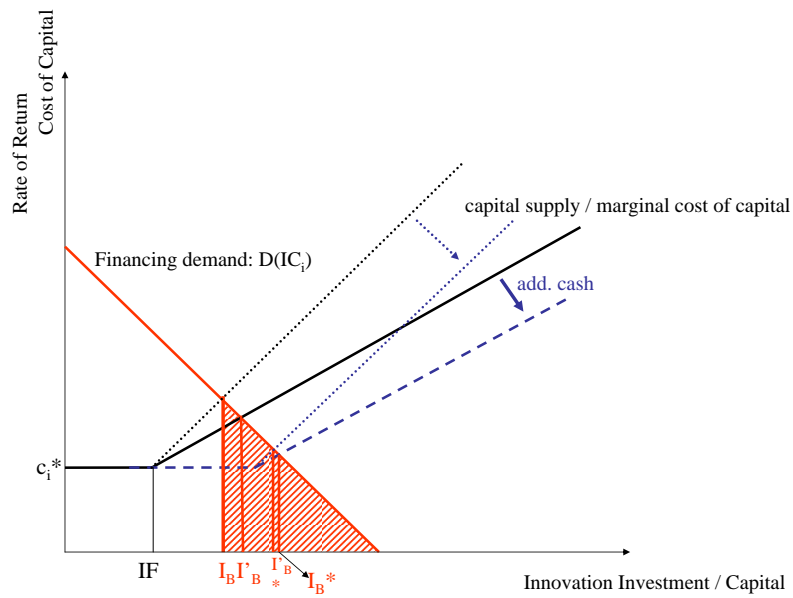


Figure 4: Homogenous innovation capacity, but different borrowing rates

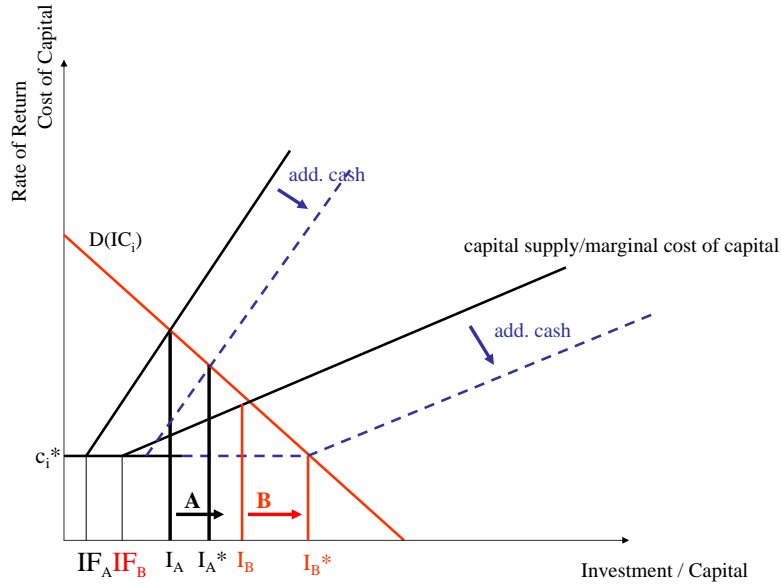


Figure 5: Homogenous innovation capacity, different available internal funds and different cash payment

Based on these theoretical considerations we derive the following hypotheses on financing constraints for innovation activities:

**Hypothesis 1** Firms with high innovation capacity should be more likely to be constrained than firms with lower innovation capacity

**Hypothesis 2** Firms with low financial resources and high innovation capacity should be more likely to be constrained than firms with the same innovation capacity, but higher levels of internal funds

**Hypothesis 3** Firms that face a larger the gap between  $c_{int}$  and  $c_{ext}$ , are more likely to be financially constrained

Financial constraints may be aggravated in situations in which credit rationing occurs as consequence of information asymmetries in the capital market (Stiglitz & Weiss 1981). Optimal amount is then basically restricted to the internally available funds.

Obviously, this basic setting does not fully account for several important aspects.

On the one hand, the nature of innovation projects itself such as the non-marginal project costs (either implement or not) and the option value resulting from the uncertainty of the returns (Dixit & Pindick 1994) are neglected. Moreover, considerations regarding the risk bearing properties of internal funds compared to loans in case of firms' bankruptcy that may affect firms financing decisions are assumed to be implicit in the firms' overall value maximization problem. Moreover, all kinds of conflicts of interest inside the firm are omitted (Jensen & Meckling 1976). Additionally, we assume that firms themselves have sufficient information about the innovation projects in order to rank investment opportunities. Nevertheless, if financing constraints occur even in the simplified setting, it seems reasonable to expect constraints if additional hurdles emerge.

## 3.2 Conceptual Framework

We investigate the presents of financing constraints for innovation based on direct survey evidence. In particular, firms were asked to imagine the following scenario: The firm unexpectedly has additional funds at its disposal amounting to 10% of the firms last year's turnover. Subsequently the firm should decide how to use this money. Firms were given the following six options of which they could chose as one or more:

- (additional) investment projects
- (additional) innovation projects
- retention / reserves
- payout to shareholders
- repayment of debt

If none of these options were appropriate, firms could also indicate that they cannot evaluate this.

This information serves as basis for the derivation of constraints indicators.

As the firms' turnover which is referred to in this question is known, we can calculate the amount of the addition funds *CASH* that the firms would receive.

We distinguish firms three different types (*TYPE*) based on the firms's answers to the question. In particular, we assume a firm being a firm of  $TYPE = 0$  if the firm indicated that it would neither invest in additional innovation project nor invest the money in any of the other options. Further, we classify a firm being a  $TYPE = 1$ -firm if the firm chose additional innovation, but also one or more of the other options. A firm is classified as being a  $TYPE = 2$ -firm if the firms chose to invest in additional innovation projects and NOT in any of the others. Thus, these firms would invest the full amount in innovation projects, while  $TYPE = 1$ -firms would only partially invest in innovation. Otherwise (*TYPE*) is set to missing.

We argue that (*TYPE*) is an ordinal variable that increases the more binding the firms' financial constraints for innovation are.

Further, generate a binary variable (*CON*), that is:

$$CON = \begin{cases} 0 & \text{if a firm is } TYPE = 0 \\ 1 & \text{if a firm is } TYPE = 1 \text{ or } TYPE = 2. \end{cases}$$

This conceptual set-up allows us to not only to estimate the likelihood of being constrained, but also the degree to which these constraints affect the firms' innovation investments. Moreover, we model the full optimization process of the firms, that is we take into account that firms invest in additional innovation projects given other alternative usages of the newly available cash.

The empirical framework to tests our hypotheses is based on the concept of financing constraints being a function of firm liquidity and innovation capacity. Thus, not only to the lack of financial resources ( $M \sim Money$ ), but also to the firms' innovation capacity ( $B \sim Brain$ ) may increase the likelihood of being constrained by increasing resource requirements. We believe that for example the share of highly qualified personnel reflects the firms' capacity to generate ideas for innovation, turn ideas into marketable products and to absorb spillovers. Further, the firms' pre-period innovation success can be regarded as reflecting the firms capacity to innovate.

Thus, the constraint  $C$  of firm  $i$  is a function

$$C = f(B_i, M_i, B_i \times M_i, controls_i).$$

While previous studies only distinguished firms that differ in terms of their financial situation, we complement previous studies by adding a second dimension. Thus, we can not only analyze the effect of the firms' innovation capacity, in previous studies usually modeled by R&D intensities, and the financing conditions, but also the additional effect of the interaction of both. Moreover, this approach does not rely on ex-ante grouping of firms such as by firm's size. This allows us to estimate our econometric models on our full data set. The survey design also allows us to observe answers of firms not yet active in innovation.

This approach enables us to distinguish between 6 types of firms that differ in terms of their innovation capacity ( $B$ ) that can be high ( $B_H$ ) or low ( $B_L$ ) and their financial resources that can be high ( $M_H$ ), medium ( $M_M$ ) or low ( $M_L$ ).

Innovation Capacity	Financial Resources		
	<i>high</i>	<i>medium</i>	<i>low</i>
<i>high</i>	$B_H M_H$	$B_H M_M$	$B_H M_L$
<i>low</i>	$B_L M_H$	$B_L M_M$	$B_L M_L$

$B$  is derived from the firm's share of highly qualified personnel reflecting the firm's innovation capacity<sup>3</sup>.

Each of these interaction terms describes a *Resource Endowment* that allows to hypothesize about the likelihood of firms in one specific state facing financing constraints for their innovation. Firms that have a low innovation capacity, but high financial resources are used as a reference category (resource endowment 0) as we assume these firms to be the least likely to face financing constraints for innovation.

<sup>3</sup>We test the sensitivity of our results to this assumption by using alternatives measures of innovation capacity in the robustness checks presented in section 5.3.

#### Resource Endowment 1

For  $B_H M_L$ , we expect financial constraints to be more likely than for our reference category. This is, because its capacity for innovation may exceed its financial possibilities.

#### Resource Endowment 2, Resource Endowment 3

For  $B_H M_{M,H}$ , we expect financial constraints to be more likely than for our reference category, but less likely than for firms with Resource Endowment 1. These firms see financing constraints in spite of the good financial situation as its capacity for innovation may exceed its financial possibilities. These firms may continuously generate new ideas that raise the need for financing investment in these projects.

#### Resource Endowment 4, Resource Endowment 5

For  $B_L M_{M,H}$ , we expect financial constraints to be more likely than for our reference category, but less likely than for firms with Resource Endowment 1 or Resource Endowment 2. Firms in that stage may be able to finance their projects by the available resources as the required resources may be lower compared to firms that have a high innovation capacity.

## 4 Data

The Mannheim Innovation Panel (MIP) provides the data used for the analysis. The MIP started in 1992 as German part of the European-wide Community Innovation Survey (CIS) with the aim to provide key innovation data for policy and research purposes. The data-set comprises firm-level survey data on the German business sector. The survey is conducted annually by the Centre for European Economic Research (ZEW) in Mannheim (Germany). It identifies process and product innovators as well as non-innovative firms in manufacturing and service industries.

The following analysis makes use of the 2007 wave of the MIP that covers the years 2005 and 2006. The present study focuses on firms in manufacturing industries (See table 7 in the Appendix).

The ordered variable *TYPE* and the binary variable *CON* represent the main dependent variables in our different models to be estimated. For our model specifications we derive a set of independent variables and control variables that are potential indicators of the whether and to which degree a firm may be subject to financial constraints with respect to their innovation activity. Our explanatory variables can be categorized into three subfields. First, innovation-related firm characteristics, second financial indicators and third, general firm level control variables.

#### **4.1 Innovation Related Firm Characteristics**

As we are interested in financial constraints for innovation activity, we want to control for differences in the innovation activities among firms.

First, we add information on whether the firm is engaged in innovative activity at all (*INNO*). This variable takes the value one if the firm either had a product or process innovation, or has ongoing or abandoned innovation activities in the period 2004-2006 or has planned to start such activities in the near future. The variable takes the value of zero if none of this was the case. As we believe that the share of highly qualified personnel (*HIGHQUAL*) reflects the firms' capacity to generate ideas for innovation, turn ideas into marketable products and to absorb spillovers, this information is used to derive the innovation capacity indicator *B*. Alternatively, the firms' innovation success (*NOVEL*) can be regarded as reflecting the firms innovation capacity ( $B^n$ ). Moreover, we want to take into account the firms' product-life-cycle patterns (*PLC*) as a shorter product-life-cycle may increase the need for resources to finance continuous innovation efforts and may imply a shorter period of generating income from existing products.

## 4.2 Financing Related Firm Characteristics

The firms' financial situation is also taken into account since we want to identify financial constraints on innovation. First, we complemented our survey data with the firms' credit rating index that we assume to reflect access to external capital (*RATING*). The credit rating is an index between 100 and 600, whereby an index of 100 represents the best rating. The credit rating indicator is a standardized measure provided by Creditreform, Germany's largest credit rating agency. Second, information about the firms' profit-turnover ratio (e.g. their return on sales) given as a classified variable with eight categories ranging from a ratio smaller than zero to a ratio larger than 15% (See table 6 in the Appendix) is used to derive an indicator of the firms' financial situation, that is the availability of internal funds. We derive 3 dummy variables to describe the financial status of the firm. First, ( $M_L$ ) is equal to one if the firm's profit-turnover ratio is smaller than zero and zero otherwise. These firms are assumed to have the lowest internal financial resources. Second, ( $M_M$ ) is equal to one if the firm's profit-turnover ratio is larger than zero, but smaller than 5% and zero otherwise. Finally, ( $M_H$ ) is equal to one if the firms' ratio is larger than 10% and zero otherwise. We interact these indicator variables with our measures for innovation capacity ( $B_L, B_H$ ).

## 4.3 General Firm Characteristics

To account for age and experience related effects on the likelihood and degree of financial constraints for innovation, we include firms' age (*AGE*) measured in years since founding and firms' size (*SIZE*) measured in number of employees. As the distributions of *SIZE* and *AGE* are highly skewed we employ the logarithms, that is  $\ln(SIZE)$  and  $\ln(AGE)$  in our models. Moreover, we add capital intensity measured as the value of a firms' assets per employee (*KAPINT*) as it can be assumed that firms that have relatively high total collateral value should suffer less from financing constraints. A similar assertion can be made with regard to group membership of a firm (*GROUP*).

We also approximate managerial firms by the *GROUP* dummy in our regressions.

This may indicate whether there additional investment are more likely if managers (roughly approximated by group) lead the firm instead of owners (or family members). While the group dummy is surely a rough proxy only, we believe that the over-investment problem is not highly relevant if  $GROUP = 0$ , as the majority of the firms in the sample are small firms which in Germany are typically owner-led or family-led firms, respectively (see Czarnitzki & Kraft (2004b) who consider different corporate governance structures and innovation for a sample of large German corporations. They indeed find that managerial firms invest more into R&D than owner-led firms. However, they also point out that the difference in investment between manager and owner-led firms declines with the degree of control exerted on the manager by the owners.) Being a family owned company (*FAMCOM*) may also have effects on financing conditions not only for innovation related projects. Most studies, however, do not distinguish between family-owned businesses and small-and-medium-sized firms in general. That means that those studies may overlook effects of the interaction of ownership and control of these firms. A owner-led firm may face a different situation when it comes to raising money for innovation projects that manager-led firms. On the hand, a family owned firm may lower agency costs due to combination of ownership and control. Moreover family owned firms may have a close and long established relationship with their house banks and therefore an advantage when it comes to lending as well.

But on the other hand there may also be reasons why financing may be limited compared to other firms of the same size and industry. First may owners tend to avoid engaging in risky and uncertain projects that would secure or even increase their market share and thereby guarantee sustainable cashflow to the firm. This may lead to a lack of internal financing involving consequences for innovation projects. Further, family owned firms may have disadvantages in raising money due to lacking specialized knowledge of the owner when it comes to convincing lenders to lend for complex innovation projects. Finally, we include a dummy variable that indicates whether the firm is located in Eastern Germany (*EAST*) to control structural differences between Eastern and Western Germany. Due to extensive governmental subsidy programs targeting Eastern German firms, in previous studies, these firms

were found to face fewer financing constraints (Czarnitzki 2006).

Table 1 shows summary statistics for the main variables. On average firms in our sample employ about 350 employees. The mean however is only 48 employees. Firms in our sample exist on average for about 20 years. The median *CASH* of the hypothetical payment is about 1.2 million €<sup>4</sup>. 68% of the firms are or were at least once engaged in some kind of innovation activity and 67% are family-owned firms. 33% are part of a group. The average credit rating is 2.27 out of 6. The median duration of the firms' product-life-cycle is 12.5 years.

When looking at our main covariates of interest, we see that most firms (52%) were classified as having a rather low innovation capacity, while being in a solid financial situation ( $B_L M_M$ ) and 22% are even in good financial situation ( $B_L M_H$ ).

The last two columns show average values of all explanatory variables for firms that were categorized as  $CON = 0$  (2909 obs.) and  $CON = 1$  (1432 obs.), respectively. The last column presents the result of t-tests on the differences of means between the two groups (\* = significant at 10%-level, \*\* = significant at 5%-level and \*\*\* = 1%-level). The test of differences in means shows that firms that would not invest in innovation if additional funds became available ( $CON = 0$ ), do not differ in terms of age from firms that would invest ( $CON = 1$ ). Moreover, we do not observe any differences between the two groups in terms of ( $B_L M_L$ ) and ( $B_L M_H$ ).

Interestingly, it turns out that firms that would invest in additional innovation projects are for instance larger on average, face shorter product-life-cycles and are less capital intensive.

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<sup>4</sup>The maximum hypothetical payment of 8.6 billion € is NO data error. This is the response of a large electricity generating and transmission company. We ran all our models with this company excluded from the data which did not significantly alter the results.

Table 1: Summary statistics

Variable	Var. type	Description	Manufacturing (2,468 obs.)						t-test			
			Mean	Std. Dev.	Min.	Max.	CON = 0 Mean	CON = 1 Mean				
<i>dependent variables:</i>												
<i>CON</i>	dummy	[0/1]	0	0.360	0	1	0.480	0	1	0.900	***	
<i>TYPE</i>	categorical	[0/1/2]	0	0.380	0	2	0.521					
<i>INNO</i>	dummy	[0/1]	1	0.684	0	1	0.465			0.562	***	
<i>resource endowment indicators:</i>												
<i>B<sub>H</sub>M<sub>L</sub></i>	dummy	[0/1]	0	0.028	0	1	0.166	0	1	0.021	0.042	***
<i>B<sub>H</sub>M<sub>M</sub></i>	dummy	[0/1]	0	0.091	0	1	0.288	0	1	0.080	0.110	***
<i>B<sub>H</sub>M<sub>H</sub></i>	dummy	[0/1]	0	0.066	0	1	0.248	0	1	0.049	0.096	***
<i>B<sub>L</sub>M<sub>L</sub></i>	dummy	[0/1]	0	0.082	0	1	0.274	0	1	0.083	0.080	***
<i>B<sub>L</sub>M<sub>M</sub></i>	dummy	[0/1]	1	0.513	0	1	0.500	0	1	0.530	0.466	***
<i>B<sub>L</sub>M<sub>H</sub></i>	dummy	[0/1]	0	0.220	0	1	0.415	0	1	0.228	0.206	***
<i>main control variables:</i>												
<i>SIZE</i>	continuous	headcount	48	351.996	1	72900	2534.748	1	72900	245.196	542.356	***
<i>AGE</i>	continuous	years	16	21.065	1	590	21.560	1	590	20.442	21.709	***
<i>CASH</i>	continuous	mio.€	1.20	19.794	0.004	8656	204.808	0.004	8656	13.517	30.982	**
<i>FAMCOM</i>	dummy	[0/1]	1	0.666	0	1	0.472	0	1	0.654	0.687	*
<i>GROUP</i>	dummy	[0/1]	0	0.331	0	1	0.471	0	1	0.310	0.368	***
<i>KAPINT</i>	continuous	mio.€/ empl.	0.05	0.176	0	15.119	0.592	0	15.119	0.213	0.108	***
<i>RATING</i>	continuous	[1-6] (1 = best)	2.18	2.273	1	6	0.653	1	6	2.297	2.230	**
<i>PLC</i>	continuous	years	12.51	18.814	1	300	21.695	1	300	20.256	16.244	***
<i>EAST</i>	dummy	[0/1]	0	0.307	0	1	0.461	0	1	0.323	0.277	**
<i>PRIVATE</i>	dummy	[0/1]	0	0.123	0	1	0.328	0	1	0.145	0.083	***
<i>PUBLIC</i>	dummy	[0/1]	0	0.038	0	1	0.192	0	1	0.038	0.039	**
<i>LIMITED</i>	dummy	[0/1]	1	0.835	0	1	0.371	0	1	0.812	0.877	***

## 5 Econometric Analysis

We follow a 3-step procedure in our econometric analysis. We start estimating Probit models on the likelihood of the occurrence of financing constraints (*CON*) such that:

$$P(CON = 1|X = x) = \Phi(x'\beta).$$

Next, we estimate ordered Probit models on the degree of the constraint (*TYPE*). The unknown parameters  $\mu$  are estimated with  $\beta$  and for all probabilities to be positive the condition  $\mu_2 > \mu_1 > 0$  must be fulfilled. However also in this model the coefficients are not equal to the marginal effects. In our case, the model has only one unknown threshold parameter such that the model can be re-written as (Greene 2003, 737-738):

$$P(type = 0|x) = 1 - \Phi(-x'\beta)$$

$$P(type = 1|x) = \Phi(\mu - x'\beta) - \Phi(-x'\beta)$$

$$P(type = 2|x) = 1 - \Phi(\mu - x'\beta)$$

Finally, we estimate multi-equation models by the method of simulated maximum likelihood to increase efficiency in our estimation by taking into account the correlation between the different answering options of the responding firm  $i$ . The variance-covariance matrix of the cross-equation error terms has values of 1 on the leading diagonal, and the off-diagonal elements are correlations to be estimated  $\rho_{ji} = \rho_{ij}$ , and  $\rho_{ii} = 1$ , for all  $i = 1, \dots, M$  (Greene 2003, 710-715).

In order to account for heterogeneity among firms, we cluster our robust standard errors by industries and region (eastern vs western Germany).

### 5.1 Probit and ordered Probit Models

Table 2 shows the estimation results from 4 different specifications of the probit model on the likelihood of facing financial constraints. Model 1 is the base-specification. Firms with a high innovation capacity ( $B_H M_L, B_H M_M, B_H M_H$ ) generally turn out to be more likely constrained than firms with low innovation capacity

( $B_L M_L, B_L M_M$ ). For firms with high innovation capacity we see that firms that additionally have low financial resources ( $B_H M_L$ ) are more likely to be constrained than firms that have a solid financial background ( $B_H M_M$ ). The hypothesis that the marginal effect of the former (23%) is indeed significantly larger than the effect of the latter (10%) is not rejected by the  $\chi^2$  test. Nevertheless, that also firms with a good financial background are more likely to be constrained if innovation capacity is high as well ( $B_H M_H$ ). For these firms we cannot state that they are significantly less likely to be constrained than firms with lower financial resources. This effect might be due to the phenomenon that these firms generate more ideas than they can finance or want finance at each point in time. Thus, these firms may use the additional money that come free of cost and invest in innovation projects that they would not conduct if this money was not available either because other investments appeared more beneficial or because a certain cash threshold for the innovation project was not reached yet.

To account access to external capital, we include *RATING* in model 2. Yet, we do not observe any effects from a bad credit rating on the likelihood of being financially constrained here. We will get back to this in the multivariate model section. To control for the effect of the amount of the hypothetical additional cash that may influence the firms response to the question in what to invest the money, we include this in model 3. We see that the marginal effects of our interaction terms are not very much altered. However, the size-effect that was significantly positive in model 1 disappears. *CASH* turns out to significantly have influenced the likelihood of firms to invest additional cash in innovation projects. The larger the expected cash inflow, the higher the probability to invest it in innovation.

Model 4 shows, however, that the positive effect only appears if the hypothetical payment is at least in the category  $\ln(CASH)_c_3$ <sup>5</sup>. The average *CASH* in category 3 is about 875.000 €<sup>6</sup>. Thus, the expected amount needs to exceed this number to encourage additional investments in innovation.

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<sup>5</sup>The 5 categories for *CASH* were constructed on the basis of up to 20%-ile, 40%-ile, 60%-ile, and larger than 80%-ile of the distribution of *CASH*. The lowest category serves as reference category.

<sup>6</sup> The average amount of class 1 is about 96000 €, of class 2 about 292000 €, of class 4 about 2.96 million € and 76 million € for class 5.

The control variables *KAPINT* and *GROUP* show the expected signs. A higher capital intensity reduces the likelihood, while being part of a group also shows a negative, yet insignificant, effect. Interestingly, family-ownership seems to increase the occurrence of financing constraints. These firms seem to be more willing to spend this additional cash on innovation than non-family-owned firms. For the duration of the product-life-cycle and firms' age<sup>7</sup>, we do not see any effects.

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<sup>7</sup>We tested different forms of *AGE*, such as non-logged or age classes. Further, we tried non-linear specifications. *AGE* did not turn out to be significant in any of these alternative specifications.

Table 2: Estimation results : probit models on the likelihood of being constrained (CON) (2,468 obs.)

Variable	Model 1		Model 2		Model 3		Model 4	
	dF/dx	(Std.Err.*)	dF/dx	(Std.Err.*)	dF/dx	(Std.Err.*)	dF/dx	(Std.Err.*)
<i>ln(SIZE)</i>	0.043***	(0.005)	0.042***	(0.006)	-0.002	(0.018)	0.005	(0.013)
<i>ln(AGE)</i>	0.005	(0.014)	0.004	(0.014)	0.002	(0.013)	-0.001	(0.013)
<i>FAMCOM</i>	0.050*	(0.019)	0.048**	(0.019)	0.055***	(0.019)	0.046**	(0.019)
<i>GROUP</i>	-0.018	(0.030)	-0.018	(0.030)	-0.034	(0.032)	-0.032	(0.031)
<i>KAPINT</i>	-0.053**	(0.025)	-0.054**	(0.026)	-0.063**	(0.029)	-0.064**	(0.028)
<i>B<sub>H</sub>M<sub>L</sub></i>	0.226***	(0.079)	0.229***	(0.079)	0.237	(0.080)	0.247***	(0.083)
<i>B<sub>H</sub>M<sub>M</sub></i>	0.096***	(0.036)	0.098***	(0.036)	0.094***	(0.035)	0.101***	(0.036)
<i>B<sub>H</sub>M<sub>H</sub></i>	0.184***	(0.050)	0.184***	(0.050)	0.174***	(0.051)	0.187***	(0.051)
<i>B<sub>L</sub>M<sub>L</sub></i>	0.023	(0.039)	0.027	(0.041)	0.034***	(0.041)	0.033	(0.041)
<i>B<sub>L</sub>M<sub>M</sub></i>	-0.025	(0.020)	-0.023	(0.020)	-0.021	(0.020)	-0.024	(0.021)
<i>ln(PLC)</i>	-0.016	(0.013)	-0.016	(0.013)	-0.017	(0.013)	-0.016	(0.013)
<i>EAST</i>	-0.033	(0.020)	-0.032	(0.020)	-0.020	(0.020)	-0.024	(0.020)
<i>RATING</i>			-0.015	(0.014)	-0.009	(0.014)	-0.026	(0.014)
<i>ln(CASH)</i>			0.042***	(0.015)	0.042***	(0.015)		
<i>ln(CASH)<sub>c_2</sub></i>							0.045	(0.045)
<i>ln(CASH)<sub>c_3</sub></i>							0.146***	(0.041)
<i>ln(CASH)<sub>c_4</sub></i>							0.180***	(0.053)
<i>ln(CASH)<sub>c_5</sub></i>							0.229***	(0.066)
Log-likelihood		-1505.396		-1504.978		-1501.189		-1496.130
McFadden's $R^2$ / Count $R^2$		0.066/0.664		0.066/0.663		0.069/0.666		0.072/0.675
McKelvey & Zavoina's $R^2$ : $R^2$		0.144		0.144		0.150		0.156
AIC / BIC		1.242/-16056.258		1.242/-16049.282		1.240/-16049.050		1.238/-16035.734
$\chi^2$ -Test of $B_H M_L > B_H M_M$		$p = 0.030^{**}$		$p = 0.029^{**}$		$p = 0.020^{**}$		$p = 0.021^{**}$
$\chi^2$ -Test of $B_H M_L > B_H M_H$		$p = 0.282$		$p = 0.270$		$p = 0.209$		$p = 0.228^{**}$
$\chi^2$ -Test of $B_H M_M > B_H M_H$		$p = 0.038^{**}$		$p = 0.044^{**}$		$p = 0.055^*$		$p = 0.045^{**}$
Joint significance of industry dummies		$\chi^2(14) = 787.75^{***}$		$\chi^2(14) = 821.80^{***}$		$\chi^2(14) = 651.72^{***}$		$\chi^2(14) = 755.67^{***}$

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%

All models 1-4 contain a constant and 14 industry dummies.

\* standard errors are robust and clustered by industries and East vs West Germany (30 clusters).

Next, we estimate ordered probit models on the degree of the constraint (*TYPE*) that allow us to investigate more accurately how the firms would want to spend the addition money. We assume a firms to be most constrained if the firms chose to invest in additional innovation projects and NOT in any of the other options. Thus, a firm of  $TYPE = 0$  would neither invest in additional innovation project nor in any of the other options. A firm of  $TYPE = 1$  would invest in additional innovation, but also spend part of the money on one or more of the other options. A firm of  $TYPE = 2$  would invest in additional innovation projects and NOT in any of the alternatives. Thus, the full amount would be spent on additional innovation projects. Table 3 shows the results from the ordered probit model. The first and second column present the coefficients and standard errors of the model and columns three to eight show the marginal effects of the likelihood of the different outcomes of *TYPE*. It turns out that a higher capital intensity increases the likelihood of being of  $TYPE = 0$ . Moreover, having a high innovation capacity, but low financial resources increases the likelihood that the firms would spend at least part of the money and even the full amount on additional innovation.

We test for heteroscedasticity and normality of our explanatory variables (Verbeek 2000, p.168). The test statistics show that homoscedasticity and normality cannot be rejected.

Table 3: Estimation results : Ordered probit model on the degree of the constraint (*TYPE*) (2,468 obs.)

Variable	Model			Outcome 0			Outcome 1			Outcome 2		
	Coef.	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)
<i>ln(SIZE)</i>	-0.044	(0.050)	0.016	(0.019)	-0.015	(0.017)	-0.001	(0.002)				
<i>ln(AGE)</i>	0.017	(0.039)	-0.006	(0.014)	0.006	(0.013)	0.001	(0.001)				
<i>FAMCOM</i>	0.140***	(0.053)	-0.051***	(0.019)	0.047***	(0.018)	0.004*	(0.001)				
<i>GROUP</i>	-0.045	(0.075)	0.016	(0.028)	-0.015	(0.025)	-0.001	(0.002)				
<i>KAPINT</i>	-0.194**	(0.078)	0.072**	(0.029)	-0.066**	(0.026)	-0.006*	(0.003)				
<i>B<sub>H</sub>M<sub>L</sub></i>	0.603***	(0.173)	-0.236***	(0.068)	0.200***	(0.047)	0.036**	(0.017)				
<i>B<sub>H</sub>M<sub>M</sub></i>	0.304***	(0.086)	-0.117***	(0.034)	0.104***	(0.030)	0.013***	(0.004)				
<i>B<sub>H</sub>M<sub>H</sub></i>	0.488***	(0.106)	-0.190***	(0.042)	0.165***	(0.034)	0.025***	(0.008)				
<i>B<sub>L</sub>M<sub>L</sub></i>	0.071	(0.103)	-0.026	(0.039)	0.025	(0.037)	0.002	(0.004)				
<i>B<sub>L</sub>M<sub>M</sub></i>	-0.060	(0.051)	0.022	(0.019)	0.024	(0.035)	-0.002	(0.002)				
<i>ln(PLC)</i>	-0.046	(0.032)	0.017	(0.012)	-0.020	(0.017)	-0.001	(0.001)				
<i>EAST</i>	-0.074	(0.055)	0.032	(0.020)	-0.015	(0.011)	-0.002	(0.001)				
<i>RATING</i>	-0.010	(0.038)	0.004	(0.014)	-0.025	(0.018)	-0.001	(0.001)				
<i>ln(CASH)</i>	0.128***	(0.044)	-0.047***	(0.016)	0.043***	(0.015)	0.004***	(0.001)				
$\mu_1$	0.774	(0.375)										
$\mu_2$	2.635	(0.373)										
Log-likelihood		-1673.275										
McFadden's $R^2$ / Count $R^2$		0.065/0.654										
McKelvey & Zavoina's $R^2$ : $R^2$		0.150										
AIC / BIC		1.380/-15697.067										
$\chi^2$ -Test of $B_{HM_L} > B_{HM_M}$		$p = 0.024^{**}$										
$\chi^2$ -Test of $B_{HM_L} > B_{HM_H}$		$p = 0.255$										
$\chi^2$ -Test of $B_{HM_M} > B_{HM_H}$		$p = 0.053^*$										
Joint significance of industry dummies		$\chi^2(14) = 421.40^{***}$										

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%

The model contains a constant and 14 industry dummies.

\* standard errors are robust and clustered by industries and East vs West Germany (30 clusters).

## 5.2 Multivariate Probit Model

The set-up of the question that serves as basis for our analysis is such that it provided several answering options. This allows responding firms to chose the option that they asses as being most attractive. To take the choice between the different option explicitly into account, we estimate a multivariate probit model. This involves simultaneous estimation of five equations. Table 4 presents the results from the multi-equation probit model. We add the firms legal form (*PUBLIC*, *LIMITED*, *PRIVATE* serves as references category) to the model. We see that the results for Equation 2, that is additional innovation projects remain. When looking at addition investment projects, it turns out that the marginal effects of our main variables of interest - the interaction terms of innovation capacity and financial resources - show a fundamentally different pattern. Having a low innovation capacity leads to a higher likelihood of choosing additional investments. Moreover, firms in eastern Germany have a higher probability of investing the cash in addition investments.

The results for equation 3 reveal that firms with high innovation capacity and low financial resources have a lower likelihood of using the additional money for building reserves than firms with low innovation capacity and relatively large financial resources. The results from equation 5 show that firms with a worse *RATING* have a higher probability of serving debt. Thus giving priority to consolidating their financial reputation, before investing in new projects. Likewise firms that lack innovation capacity would use the money to serve their debt.

Table 4: Estimation results: Multivariate probit model on the likelihood of being constrained (CON) (2,468 obs.)

Variable	Equ. 1		Equ. 2		Equ. 3		Equ. 4		Equ. 5	
	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)
$\ln(SIZE)$	0.053***	(0.017)	0.002	(0.018)	-0.008	(0.018)	-0.028**	(0.014)	0.050***	(0.018)
$\ln(AGE)$	-0.012	(0.013)	0.001	(0.014)	-0.013	(0.014)	-0.018	(0.011)	-0.004	(0.015)
FAMCOM	0.027	(0.023)	0.053**	(0.023)	0.038	(0.024)	-0.045**	(0.020)	0.031	(0.024)
GROUP	-0.090***	(0.025)	-0.038	(0.025)	-0.011	(0.026)	0.113***	(0.023)	-0.066**	(0.026)
KAPINT	-0.029	(0.020)	-0.076**	(0.037)	-0.053**	(0.025)	0.019	(0.016)	0.050**	(0.020)
$B_H M_L$	0.016	(0.059)	0.239***	(0.067)	-0.217***	(0.056)	-0.103***	(0.033)	0.121*	(0.067)
$B_H M_M$	0.002	(0.038)	0.096**	(0.042)	0.129***	(0.042)	-0.123***	(0.021)	0.049	(0.043)
$B_H M_H$	0.004	(0.043)	0.179***	(0.048)	0.069	(0.048)	-0.095***	(0.026)	-0.065	(0.048)
$B_L M_L$	0.063*	(0.036)	0.030	(0.042)	-0.026	(0.042)	-0.058**	(0.028)	0.246***	(0.040)
$B_L M_M$	0.050**	(0.025)	-0.025	(0.026)	0.048*	(0.026)	-0.067***	(0.021)	0.102***	(0.027)
$\ln(PIC)$	-0.012	(0.011)	-0.015	(0.011)	-0.001	(0.011)	0.011	(0.009)	0.017	(0.011)
EAST	0.082***	(0.021)	-0.017	(0.023)	-0.035	(0.024)	-0.078***	(0.018)	0.020	(0.024)
RATING	-0.027*	(0.015)	-0.013	(0.017)	-0.022	(0.017)	-0.018	(0.014)	0.067***	(0.018)
$\ln(CASH)$	-0.014	(0.014)	0.039**	(0.015)	0.004	(0.016)	0.021*	(0.012)	-0.036**	(0.016)
PUBLIC	-0.121*	(0.066)	-0.051	(0.060)	0.151**	(0.064)	0.293***	(0.074)	-0.003	(0.065)
LIMITED	-0.066**	(0.029)	0.054*	(0.032)	0.084***	(0.032)	0.147***	(0.020)	-0.102***	(0.034)
Log-likelihood					-7181.928					
$\chi^2$ -Test $B_H M_L > B_H M_M$	$p = 0.439$		$p = 0.024**$		$p = 0.000***$		$p = 0.089*$		$p = 0.132$	
$\chi^2$ -Test $B_H M_L > B_H M_H$	$p = 0.456$		$p = 0.219$		$p = 0.000***$		$p = 0.415$		$p = 0.005***$	
$\chi^2$ -Test $B_H M_M > B_H M_H$	$p = 0.483*$		$p = 0.057*$		$p = 0.127$		$p = 0.172$		$p = 0.017**$	
Joint sign.										
industry dummies										
$\chi^2(70) = 177.09***$										

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%

The model contain a constant and 14 industry dummies.

\* standard errors are robust and clustered by industries and East vs West Germany (30 clusters).

### 5.3 Robustness Checks

We test the robustness of our results by estimating alternative specifications. First, we re-estimate the previous models now using a different indicator for the firms' innovation capacity. We now define a firm to have a high innovation capacity if it was successful with its past innovation projects. More particularly, if the firm has introduced at least one new product to the market in the pre-survey period, thus  $NOVEL = 1$ .

Tables 5 and 6 show the results from the probit and ordered probit models, respectively. While the effects of the general firm characteristics remain almost unchanged, interestingly, the effects of the interaction terms do change. Here, it turns out that firms with  $B_h M_l$  are significantly more likely to be constrained than any of the other 6 possible combinations. The test of difference between  $B_h M_l$  and  $B_h M_h$  is no longer rejected.

This result supports our hypothesis that innovation capacity in terms of highly qualified people tends to generate more ideas than the firm is able to pursue. Thus, exceeding the firm's resources although the financial situation is good.

If innovation capacity however is measured by innovation success, that is experience in translating ideas into products rather than just generating the ideas, results change. In this case firms with high innovation capacity and good financial background are still more likely to be constrained than firms with low capacity and good financial background, but less likely than firms that lack the financial resources.

As a second check, we want to test whether being a firm that was active in innovation before affects our results. For this purpose, we estimate a two-stage selection model for both  $CON$  and  $TYPE$ . The variable  $DIVERS$  serves as exclusion restriction in the first stage. We assume that a firm's likelihood to innovate is positively affected by its diversification of its product portfolio, while its likelihood to face financial constraints is not affected by  $DIVERS$ <sup>8</sup>. Table 7 presents the results. We see that in Stage 1 that estimates the likelihood of being an innovator, the effects of firms' size is positive and the effect of firms' age is negative. Further, we included the firms' export intensity  $EXINT$  in the first stage of the model. The likelihood-ratio

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<sup>8</sup> $DIVERS$  turns out insignificant in all variations of our  $CON$  models.

test, however, does not reject the hypothesis of independents of the two equation for stage 1 and stage 2. Thus, we do not face a selection problem here. Consequently, the results not change considerably compared to the models presented in section 5.1. Nevertheless, we observe that firms with high innovation capacity and solid financial background are no longer more likely to be constrained than firms with low innovation capacity. This may point to the fact that for these firms other spending options appear to be more attractive.

Table 5: Estimation results : probit models on the likelihood of being constrained (*CON*) (*2,468 obs.*) with alternative measure for innovation capacity (*NOVEL*)

Variable	Model 1		Model 2		Model 3		Model 4	
	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)
<i>ln(SIZE)</i>	0.026***	(0.006)	0.024***	(0.014)	-0.024	(0.018)	-0.014	(0.014)
<i>ln(AGE)</i>	0.002	(0.014)	0.001*	(0.017)	-0.001	(0.014)	-0.004	(0.013)
<i>FAMCOM</i>	0.035**	(0.017)	0.033***	(0.028)	0.041**	(0.018)	0.032*	(0.017)
<i>GROUP</i>	-0.012	(0.028)	-0.013	(0.024)	-0.031	(0.030)	-0.028	(0.030)
<i>KAPINT</i>	-0.049**	(0.023)	-0.051**	(0.054)	-0.062**	(0.027)	-0.062**	(0.027)
<i>B<sub>H</sub>M<sub>L</sub></i>	0.349***	(0.052)	0.356***	(0.037)	0.367***	(0.054)	0.371***	(0.055)
<i>B<sub>H</sub>M<sub>M</sub></i>	0.192***	(0.038)	0.195***	(0.045)	0.195***	(0.037)	0.195***	(0.038)
<i>B<sub>H</sub>M<sub>H</sub></i>	0.227***	(0.045)	0.226***	(0.049)	0.222***	(0.045)	0.228***	(0.042)
<i>B<sub>L</sub>M<sub>L</sub></i>	0.018	(0.049)	0.021	(0.023)	0.030	(0.050)	0.029	(0.050)
<i>B<sub>L</sub>M<sub>M</sub></i>	-0.022	(0.023)	-0.021	(0.013)	-0.019	(0.023)	-0.022	(0.023)
<i>ln(PLC)</i>	-0.010	(0.013)	-0.010	(0.020)	-0.011	(0.013)	-0.010	(0.013)
<i>EAST</i>	-0.020	(0.020)	-0.018	(0.016)	-0.005	(0.020)	-0.010	(0.021)
<i>RATING</i>			-0.021	(0.006)	-0.015	(0.016)	-0.014	(0.016)
<i>ln(CASH)</i>					0.047***	(0.015)		
<i>ln(CASH)<sub>c_2</sub></i>							0.054	(0.042)
<i>ln(CASH)<sub>c_3</sub></i>							0.149***	(0.044)
<i>ln(CASH)<sub>c_4</sub></i>							0.185***	(0.057)
<i>ln(CASH)<sub>c_5</sub></i>							0.245***	(0.066)
Log-likelihood	-1475.196		-1474.401		-1469.746		-1465.321	
McFadden's $R^2$ / Count $R^2$	0.085/0.685		0.085/0.685		0.088/0.689		0.091/0.687	
McKelvey & Zavoina's $R^2$ : $R^2$	0.169		0.171		0.177		0.182	
AIC / BIC	1.217/-16116.659		1.218/-16110.436		1.215/-16111.935		1.213/-16097.352	
$\chi^2$ -Test $B_{HM_L} > B_{HM_M}$	$p = 0.004^{***}$		$p = 0.004^{***}$		$p = 0.003^{***}$		$p = 0.003^{***}$	
$\chi^2$ -Test $B_{HM_L} > B_{HM_H}$	$p = 0.007^{***}$		$p = 0.008^{***}$		$p = 0.004^{***}$		$p = 0.006^{***}$	
$\chi^2$ -Test $B_{HM_M} > B_{HM_H}$	$p = 0.201$		$p = 0.230$		$p = 0.263$		$p = 0.219$	
Joint sign.								
industry dummies	$\chi^2(14) = 880.44^{***}$		$\chi^2(14) = 813.06^{***}$		$\chi^2(14) = 1098.24^{***}$		$\chi^2(14) = 1081.23^{***}$	

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%

All models 1-4 contain a constant and 14 industry dummies.

\* standard errors are robust and clustered by industries and East vs West Germany (30 clusters).

Table 6: Estimation results : Ordered probit model on the degree of the constraint (*TYPE*) (*2,468 obs.*) with alternative measure for innovation capacity (*NOVEL*)

Variable	Model			Outcome 0			Outcome 1			Outcome 2		
	Coef.	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)
<i>ln(SIZE)</i>	-0.108**	(0.051)	0.040**	(0.019)	-0.037**	(0.018)	-0.003**	(0.002)				
<i>ln(AGE)</i>	0.005	(0.040)	-0.002	(0.015)	0.002	(0.014)	0.001	(0.001)				
<i>FAMCOM</i>	0.095**	(0.048)	-0.035**	(0.017)	0.032**	(0.016)	0.003**	(0.001)				
<i>GROUP</i>	-0.028	(0.069)	0.010	(0.026)	-0.010	(0.023)	-0.001	(0.002)				
<i>KAPINT</i>	-0.191**	(0.075)	0.070**	(0.028)	-0.065**	(0.025)	-0.006**	(0.003)				
<i>B<sub>H</sub>M<sub>L</sub></i>	0.781***	(0.119)	-0.304***	(0.044)	0.250***	(0.033)	0.053***	(0.013)				
<i>B<sub>H</sub>M<sub>M</sub></i>	0.484***	(0.105)	-0.186***	(0.041)	0.165***	(0.036)	0.021***	(0.006)				
<i>B<sub>H</sub>M<sub>H</sub></i>	0.566***	(0.115)	-0.220***	(0.045)	0.191***	(0.038)	0.029***	(0.008)				
<i>B<sub>L</sub>M<sub>L</sub></i>	0.099	(0.128)	-0.037	(0.049)	0.034	(0.044)	0.003	(0.005)				
<i>B<sub>L</sub>M<sub>M</sub></i>	-0.049	(0.061)	0.018	(0.022)	-0.017	(0.021)	-0.001	(0.002)				
<i>ln(PLC)</i>	-0.030	(0.032)	0.011	(0.012)	-0.010	(0.011)	-0.001	(0.001)				
<i>EAST</i>	-0.033	(0.055)	0.012	(0.020)	-0.011	(0.019)	-0.001	(0.002)				
<i>RATING</i>	-0.020	(0.046)	0.007	(0.017)	-0.007	(0.015)	-0.001	(0.001)				
<i>ln(CASH)</i>	0.143***	(0.044)	-0.053***	(0.016)	0.049***	(0.015)	0.004***	(0.001)				
Log-likelihood	-1648.659											
McFadden's $R^2$ / Count $R^2$	0.079/0.679											
McKelvey & Zavoina's $R^2$ : $R^2$	0.168											
AIC / BIC	1.360/-15746.299											
$\chi^2$ -Test $B_H M_L > B_H M_M$	$p = 0.019^{**}$											
$\chi^2$ -Test $B_H M_L > B_H M_H$	$p = 0.051^*$											
$\chi^2$ -Test $B_H M_M > B_H M_H$	$p = 0.161$											
Joint sign.												
industry dummies	$\chi^2(14) = 434.120^{***}$			$\chi^2(14) =^{***}$			$\chi^2(14) =^{***}$					

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%

The model contains a constant and 14 industry dummies.

\* standard errors are robust and clustered by industries and East vs West Germany (30 clusters).

Table 7: Estimation results: Probit / Ordered Probit model with selection (2,452 obs.)

Variable	Probit Model			Ordered Probit Model			
	Stage 1: INNO	Stage 2: CON	Stage 1: INNO	Stage 2: TYPE	Outcome 0	Outcome 1	Outcome 2
	dF/dx	dF/dx	dF/dx	dF/dx	dF/dx	dF/dx	dF/dx
$\ln(SIZE)^+$	0.047***	-0.019	0.047***	0.036	-0.031	-0.005	-0.005
$\ln(AGE)$	-0.044***	0.013	-0.044***	-0.020	0.017	0.003	0.003
$FAMCOM$	0.008	0.063**	0.009	-0.059**	0.052**	0.007*	0.007*
$GROUP$	0.059**	-0.056*	0.059**	0.029	-0.026	-0.004	-0.004
$KAPINT^+$	-0.005	-0.070	-0.005	0.079*	-0.069*	-0.010*	-0.010*
$B_H M_L$		0.284***		-0.272***	0.202***	0.071**	0.071**
$B_H M_M$		0.046		-0.081*	0.069*	0.012*	0.012*
$B_H M_H$		0.156***		-0.178***	0.144***	0.034**	0.034**
$B_L M_L$		0.061		-0.048	0.041	0.007	0.007
$B_L M_M$		0.001		0.003	-0.002	-0.001	-0.001
$\ln(PLC)$	0.003	-0.021	0.003	0.021	-0.018	-0.003	-0.003
$EAST$	-0.031	-0.009	-0.031	0.021	-0.018	-0.003	-0.003
$RATING$		-0.013		0.003	-0.003	-0.001	-0.001
$\ln(CASH)$		0.040**		-0.049**	0.041**	0.006**	0.006**
$EXINT^+$	0.003***		0.003***				
$DIVERS$	0.023***		0.023***				
Log-likelihood		-2366.328			-2532.673		
Rho		-0.072			-0.073		
$\chi^2$ -Test $B_H M_L > B_H M_M$		$p = 0.001$ ***			$p = 0.003$ ***		
$\chi^2$ -Test $B_H M_L > B_H M_H$		$p = 0.048$ **			$p = 0.083$ *		
$\chi^2$ -Test $B_H M_M > B_H M_H$		$p = 0.027$ **			$p = 0.032$ **		
Joint sign.							
industry dummies		$\chi^2(28) = 188.790$ ***			$\chi^2(28) = 186.88$ ***		

Significance levels : \* : 10% \*\* : 5% \*\*\* : 1%

Both models contain constants and 14 industry dummies. (+): Lagged values (t-1) are used in Stage 1.

$DIVERS$  serves as exclusion restriction. It is insignificant in all specifications of the  $CON$  probit models.

## 6 Conclusion

In imperfect capital markets financing conditions for innovation activities may be one major reason for welfare reducing under-invest in innovation activities. Especially, in the case of innovation investments, that involve R&D activities and other expenditures that are to a large extent sunk, lenders may require a premium on the interest rate.

Thus, firms that have limited internal funds and have to rely on external financing face financing constraints and therefore may have to leave some of their innovation projects on the shelf that would be potentially profitable, but cannot be financed given the 'risk-premium' on the cost of capital.

This article contributes to the literature on financing constraints for innovation in two ways. First, a new approach toward the measuring of financial constraints is being introduced. From our survey data we identify firms that indicated to invest additional cash in innovation projects. We interpret a positive expansionary effect from additional cash on innovation investments as result from financing constraints that curtail these firms' innovation investments at sub-optimal levels.

Our conceptual set-up allows us to estimate the likelihood of being constrained as well as the degree to which these constraints affect the firms' innovation investments. This distinction is derived from the information whether firms would invest the full amount or only parts of it in additional innovation projects.

Additionally, we consider innovation investments as part of firms' overall optimization process. Particularly, we take into account that firms invest in additional innovation projects given other alternative usages of the newly available cash.

Second, we derive a concept that attributes financing constraints not only to the lack of financial resources, but also to the firms' innovation capacity. A relatively high innovation capacity may increase the likelihood firms of being constrained by increasing resource requirements.

Our econometric analysis supports the hypotheses derived from our theoretical considerations in section 3. The results show that innovation capacity is the fac-

tor driving financing constraints for innovation. Our results show that firms with higher innovation capacity are more likely to have unexploited innovation projects, independent of their financial background (Hypothesis 1).

For firms with high innovation capacity, but different financial resources, our results show that firms with low levels of internal funds are more likely to be constrained in their innovation activities than their more liquid counterparts (Hypothesis 2).

Thus, we find that firms with a high innovation capacity, but low financial resources turn out most likely to be constrained. Yet, we also observe constraints for financially sound firms that may have to put some of their ideas on the shelf.

Hypothesis 3 is supported by the significant effect of a low capital intensity on the likelihood and the degree of being constrained. This indicates, that firms that face a larger the gap between  $c_{int}$  and  $c_{ext}$  due to a lower overall collateral value, are more likely to be financially constrained. Moreover, we observe a negative sign for firms that are part of group and for firms that have a longer product life-cycle.

Moreover, the multidimensional analysis taking all options for usage of the additional money into account reveals that firms with a bad credit rating would primarily repay debt instead of investing it in additional innovation projects.

We further see that family-owned businesses are more likely to invest additional cash in innovation projects than firms with other ownership structures. This may, however, indicate that these firms have a general preference for internal financing. Future analysis will be directed to this issues. In particular, we expect that family-run firms would answer differently, if not cash, but loans at a comparatively low interest rate would have been offered. Hence, further analysis will address the fact how much the results depend on the fact that the question concerns additional internal funds only.

These results have implications for innovation policy. If innovation capacity is the driving force behind financing constraints, governmental action to support private invest in innovation activities should focus the factors that form the innovation capacity of firms such as the accumulation of human capital incorporated in highly qualified personnel.

## 7 Appendix

Table 8: Industries and *CON* by industries(2,468 obs.)

Number	Industry*	Frequency	%	Mean prob. of <i>CON</i>		Mean prob. of <i>TYPE</i>	
				TYPE(0)	TYPE(1)	TYPE(0)	TYPE(1)
1	mining	78	3.16	0.154	84.62	15.38	0.00
2	food/tobacco	172	6.97	0.285	71.51	27.33	1.16
3	textiles	113	4.58	0.336	66.37	32.74	0.88
4	paper/wood/print	250	10.13	0.284	71.60	27.60	0.80
5	chemical	162	6.56	0.432	56.79	38.89	4.32
6	plastics/rubber	143	5.97	0.364	63.64	34.27	2.10
7	glas/ceramics	118	4.78	0.398	60.17	39.83	0.00
8	metal	312	12.64	0.369	63.14	36.22	0.64
9	machinery	265	10.74	0.426	57.36	39.25	3.40
10	electr. eng.	186	7.54	0.505	49.46	46.77	3.76
11	medicine/optic/processing	193	8.82	0.523	47.67	48.70	3.63
12	vehicles	100	4.05	0.460	54.00	44.00	2.00
13	furniture	121	4.90	0.339	66.12	32.23	1.65
14	energy/water	142	4.75	0.148	85.21	14.08	0.70
15	construction	113	4.58	0.150	84.96	15.04	0.00
	Total	2,468	100.00	0.359	64.06	34.12	1.82

\*Industry definition according to NACE sectors

Table 9: Profit-Turnover Ratio Categories (2,468 obs.)

<b>Profit-Turnover Ratio</b>	<b>Frequency</b>	<b>%</b>	<b>Cum.</b>
<0%	272	11.02	11.02
0%-<2%	419	16.98	28.00
2%-<4%	467	18.92	46.92
4%-<7%	604	24.47	71.39
7%-<10%	348	14.10	85.49
10%-<15%	209	8.47	93.96
>=15%	149	6.04	100.00
Total	2,468	100.00	

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