Hottenrott, Hanna; Peters, Bettina

Working Paper

Innovative capability and financing constraints for innovation more money, more innovation?

ZEW Discussion Papers, No. 09-081 [rev.]

Provided in cooperation with:
Zentrum für Europäische Wirtschaftsforschung (ZEW)

Discussion Paper No. 09-081

Innovative Capability and Financing Constraints for Innovation
More Money, More Innovation?

Hanna Hottenrott and Bettina Peters

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Discussion Paper No. 09-081

Innovative Capability and Financing Constraints for Innovation More Money, More Innovation?

Hanna Hottenrott and Bettina Peters

First Version: December 2009
This Version: March 2011

Non-technical Summary

Economic theory suggests that financing constraints may occur due to capital market imperfections. These particularly affect investments in innovation projects as such projects are typically characterized by a high degree of uncertainty, complexity and specificity. Financing innovation externally is thus likely to be more costly compared to financing of other investment. Hence, internal sources of financing are crucial for the implementation of innovation projects. However, internal funds are not inexhaustible either. They are naturally limited and raising new equity may be costly and often undesired. Financing constraints, however, may not affect all firms to the same extent. This paper addresses the question of which firms face financing constraints. Such identification is particularly interesting for policy makers in order to design effective policy schemes as financing constraints lead to a suboptimal level of investment in innovation.

In contrast to previous empirical studies, our analysis is based on the idea of an ideal test for identifying financial 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 unexploited investment opportunities that were not profitable using more costly external finance'. That is, these firms have been financially constrained. This study contributes to the literature in the following three main aspects. First, we employ a direct indicator derived from survey information in which firms were offered a hypothetical cash payment. Second, we account for the firm's choice between alternatives of use for the money. Third, we introduce the concept of innovative capability and how it affects financing constraints for innovation.

The results from our econometric analysis show that financial constraints for innovation do not depend on the availability of funds per se, but are driven by innovative capability through increasing resource requirements. That is, firms with high innovative capability but low financial resources are more likely constrained than others. Yet, we also observe constraints for financially sound firms that may have to put some of their ideas on the shelf. Firms with low innovative capability choose other options, such as investment in physical capital. Taking account of all options for usage of the additional money, we further find in contrast to the innovation decision, the decision to serve debt is to a large extent driven by the financial background. Firms with low internal funds or a bad credit rating would primarily repay debt instead of investing additional cash in innovation projects.

Das Wichtigste in Kürze

Unvollkommenen Kapitalmärkte führen dazu, dass sich Unternehmen Einschränkungen bei der Finanzierung von Investitionsvorhaben gegenübersehen. Unzureichender Zugang zu Finanzierungsquellen kann insbesondere bei Investitionen in Innovationsprojekte eine Rolle spielen, da Innovationsprojekte im Allgemeinen durch einen hohen Grad an Unsicherheit, Komplexität und Spezifität gekennzeichnet sind. Die externe Finanzierung von Innovationsprojekten ist daher - sofern verfügbar - vergleichsweise teuer. Unternehmen sind bei der Finanzierung von Innovationsprojekten daher auf interne Mittel angewiesen, wenngleich diese ebenfalls nicht unbegrenzt zur Verfügung stehen.
Theoretische Überlegungen zeigen, dass projekt- und unternehmensspezifische Faktoren Finanzierungsrestriktionen beeinflussen, sodass zu erwarten ist, dass nicht alle Unternehmen im gleichen Ausmaß davon betroffen sind. Die vorliegende Studie befasst sich mit der Identifizierung restringierter Firmen. Die Identifizierung ist für politische Entscheidungsträger von besonderem Interesse bei der Gestaltung effektiver Politikmaßnahmen zur Förderung von Innovationstätigkeiten.
Im Gegensatz zur bisherigen Literatur basiert die vorliegende Studie auf der Idee eines von Hall (2008) vorgeschlagenen idealen Tests zur Identifizierung restringierter Unternehmen. Die Idee des Tests besteht darin, Unternehmen zusätzliche Mittel frei zur Verfügung zustellen. Werden die zusätzlichen Mittel für Innovationsprojekte anstelle von anderen Verwendungsmöglichkeiten (Rücklagen, Investitionen, Ausschüttung, Schuldenrückzahlung) eingesetzt, kann daraus der Rückschluss gezogen werden, dass das Unternehmen bisher aufgrund mangelnder Finanzierung Innovationsprojekte nicht durchführen konnte.
Die vorliegende Studie leistet einen Beitrag zur bestehenden Literatur in dreierlei Hinsicht. Erstens verwenden wir einen neuen, direkten Indikator zur Identifizierung restringierter Unternehmen. Zweitens berücksichtigen wir in der Innovationsentscheidung alternative Verwendungsmöglichkeiten für zusätzliche liquide Mittel. Drittens führen wir das Konzept der Innovationskapazität in seiner Rolle für Finanzierungsrestriktionen ein.
Die Ergebnisse der ökonometrischen Analyse zeigen, dass Finanzierungsrestriktionen nicht per se durch die Verfügbarkeit von finanziellen Mittel abhängen, sondern in entscheidenem Maße von der Innovationskapazität der Unternehmen beeinflusst werden. Unternehmen mit vergleichsweise hoher Innovationskapazität und geringen liquiden Mitteln sind zwar am wahrscheinlichsten von Finanzierungsrestriktionen betroffen, gleichwohl sind auch Unternehmen mit hoher Innovationskapazität und solidem finanziellen Hintergrund finanziell restringiert. Unternehmen mit geringer Innovationskapazität wählen dagegen andere Verwendungszwecke für die zusätzlichen liquiden Mittel, z.B. Investitionen in Sachkapital. Die Berücksichtigung aller Verwendungsalternativen zeigt darüber hinaus, dass die Entscheidung Schulden zurückzuzahlen vor allem von der eigenen finanziellen Ressourcenausstattung abhängt. Das bedeutet, dass Unternehmen mit geringen internen Mitteln oder einer niedrigen Kreditwürdigkeit die zusätzlichen Mittel zunächst zur Begleichung von Schulden einsetzen.

INNOVATIVE CAPABILITY AND FINANCING CONSTRAINTS FOR INNOVATION: MORE MONEY, MORE INNOVATION?*

Hanna Hottenrott[a,b] and Bettina Peters[b,c]

[a] *K.U.Leuven, Dept. of Managerial Economics, Strategy and Innovation*
[b] *Centre for European Economic Research (ZEW), Mannheim*
[c] *University of Zurich*

First version: December 2009
Revised version: March 2011

Abstract: This study presents a novel empirical approach to identify financing constraints for innovation based on the concept of an ideal test as suggested by Hall (2008). Firms were offered a hypothetical payment and were asked to choose between alternatives of use. If they selected additional innovation projects, they must have had some unexploited investment opportunities that were not profitable using more costly external finance. We attribute constraints for innovation not only to lacking financing, but also to firms' innovative capability. Econometric results show that financial constraints do not depend on the availability of internal funds per se, but that they are driven by innovative capability.

Keywords: Innovation, financing constraints, innovative capability, multivariate probit models

JEL-Classification: O31, O32, C35

* The authors are grateful to the European Cooperation in Science and Technology (COST), the STRIKE network and the Flemish Science Foundation (FWO) for financial support. We would also like to thank Rene Belderbos, Dirk Czarnitzki, Georg Licht, Christian Rammer, Otto Toivanen and Reinhilde Veugelers, participants at conferences of the European Economic Association (EEA 2009), the European Association for Research in Industrial Economics (EARIE 2009), the International Industrial Organization (IIOC 2010) as well as seminars participants at K.U.Leuven, ZEW and Zurich University and an anonymous referee for valuable comments. Any errors remain those of the authors.

1 Introduction

In economic research and policy practice it is a widely accepted view that innovation constitutes an important driving force of firm-level productivity, competitiveness, and sustainable economic growth.[1] Consequently, it is a concern for both policy makers and industry practitioners that financing constraints due to imperfections in capital markets reduce investments in innovation below desired levels. Investment in innovation may be particularly affected by financial constraints since information asymmetries exist due to the complexity, specificity, and high degree of uncertainty of innovation projects. This makes it difficult for outsiders to judge the projects' potential value. Moreover, firms may be reluctant to reveal details of innovation projects to prospect investors. Therefore, financing innovation externally may be more costly compared to other investments.[2] Internal sources of financing are thus crucial for the implementation of innovation projects.[3] However, internal funds are not inexhaustible either. Cash flow is naturally limited and raising new equity may be costly and often unwanted.[4] Financing constraints, however, may not affect all firms to the same extent. The identification of constrained firms is particularly interesting for policy makers in order to design effective policy schemes aimed at preventing welfare-reducing suboptimal investment in innovation. In contrast to previous empirical studies which tested the presence of financing constraints indirectly by the sensitivity of investment in research and development (R&D) to changes in internal funds, this study takes a direct approach. It is based on the concept of an ideal test for identifying financial 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, then the firm must have had some unexploited investment opportunities that were not profitable using more costly external finance". That is, these firms had been financially constrained.

[1]See e.g. Solow (1957), Griliches (1980) and the references cited in the survey by Hall (2008).

[2]As for instance suggested by Meyer and Kuh (1967), Stiglitz and Weiss (1981) and Anton and Yao (2002).

[3]See Leland and Pyle (1977), Bhattacharya and Ritter (1983), Hall (1990, 1992) as well as Himmelberg and Petersen (1994).

[4]See Carpenter and Petersen (2002). Recently, Brown and Petersen (2009) and Brown, Fazzari and Petersen (2009) observe a significant increase in the share of new stock issues in the financial structure of young U.S. manufacturing firms and attribute this to improvements in equity markets. In a comparable analysis, Martinsson (2010) find a similar shift in in- and external equity for young high-tech firms in the UK, but not in Continental Europe. The latter appeared to have experienced a supply shift in cash flow only.

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

The econometric results show that financial constraints do not depend on the availability of internal funds per se, but that they are driven by innovative capability through increasing resource requirements. Firms with high innovative capability but low financial resources are 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. Taking account of all options for using additional money, the multidimensional analysis reveals some further interesting results. For example, firms with bad credit ratings would primarily repay their debt.

This article briefly reviews previous research in section 2. Section 3 describes the theoretical framework of our study and sets out the role of innovative capability for financing constraints. The data and econometric model specifications as well the results are presented in sections 4 and 5, respectively. Section 6 concludes.

2 Financing Constraints for Innovation: What do we Know?

In principle there are two sources for financing innovation projects. External sources include bank loans or other debt contracts whereas internal sources basically originate from retained profits or (new) equity. In their seminal article Modigliani and Miller (1958) show that in markets that are characterized by no taxes, no bankruptcy costs, and no asymmetric information, investment decisions are indifferent to capital structure. Hence, in a neo-classical world with frictionless markets sources of financing would not matter. However, starting with the work of Arrow (1962) and Nelson (1959) numerous articles have elaborated on the reasons why the source of financing matters and why it particularly matters for investments in innovation (Stiglitz and Weiss 1981, Stiglitz 1985, Greenwald, Stiglitz and Weiss 1984, Bhattacharya and Ritter 1983, Anton and Yao 2002). Information asymmetries that arise due to the specific characteristics of innovation cause lenders or investors to demand a 'premium' on their required rate of return in the sense of Akerlof (1970).

Besides information asymmetries, the intangible nature of the asset that is being created by R&D usually makes external fund raising more costly than for other types of investment. A large fraction of innovation investments, particularly R&D, is sunk and cannot be redeployed. Debt holders such as banks prefer physical and redeployable assets as security for their loans since these can be liquidated in case of project failure or bankruptcy (Williamson 1988, Alderson and Betker 1996). 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 returns. In addition, serving debt reduces cash flow for future investments (see Hall 1992, 2002).

Empirical evidence corroborates that firms first and foremost use internal funds to finance innovation projects (as compared to debt) indicating a gap in the respective cost of capital (Leland and Pyle 1977, Bhattacharya and Ritter 1983, Hall 1990, 1992, Himmelberg and Peterson 1994, Bougheas, Görg and Strobl 2003, Czarnitzki and Hottenrott 2011b). Internal funds, however, are naturally limited and raising new equity may be costly and often unwanted. Consequently, the extent to which financial constraints are binding depends on the firms' ability to raise funds under the conditions of imperfect capital markets.

Measuring and identifying financial constraints represents a main challenge in empirical research. Since the seminal work of Fazzari, Hubbard and Petersen (1988), econometric studies have tried to detect financial constraints by analyzing investments' sensitivities to changes in available financial resources, most often cash flow. Excess sensitivities were regarded as indirectly reflecting the firms' lack of access to the credit market.[5] This methodology has subsequently been applied to investment in R&D. Theoretical literature states that asym-

[5] See for example Schiantarelli (1996), Hubbard (1998), Bond and Van Reenen (2007) for surveys of the literature.

metric information, moral hazard in borrower-lendership, intra-firm organizational structure and other institutional factors may lead to financial constraints. They are thus expected to depend on certain project, firm, and institutional characteristics. In order to observe more than an average effect, researchers usually split their sample or focus on a particular group of firms a priori.[6] Financing constraints for R&D were found to depend on certain project and firm characteristics. Empirical studies, however, have not always provided unambiguous results (see Hall 2002, 2008 and Hall and Lerner 2010 for surveys of the literature).

Most of these empirical studies suffer from limitations in data availability. Many of them look at either large, stock market firms or at exceptionally small firms. More severe limitations arise from the conceptual set-up. Kaplan and Zingales (1997, 2000) first questioned whether the relationship between cash flow and investment is a sufficient indication of financial constraints (see also Cleary 1999, Fazzari et al. 2000, Aydogan 2003 and Moyen 2004). Especially in the case of large firms, free cash flow levels may be determined by accounting as well as dividend policies aimed at mitigating moral hazard problems (Jensen and Meckling 1976, Jensen 1986, Dhanani 2005). Additionally, a positive relationship between investment and cash flow may simply reflect that both of them correlate with promising market demand. Finally, firms tend to smooth R&D spending over time leading to difficulties in measuring the impact of changes in cash in one period on subsequent investments (Hall, Griliches and Hausman 1986, Lach and Schankerman 1988).

Consequently, recent studies investigate firms' access to external funds more directly through the analysis of standardized credit ratings (Czarnitzki 2006, Czarnitzki and Hottenrott 2011a,b) or credit requests (Piga and Atzeni 2007). The main concern using credit requests, however, relates to a selectivity problem. The most constrained firms may not expect to get external funding and hence not ask for it. Moreover, in previous studies firms that have not been innovative in the past due to a constraint may not be paid the necessary attention to. As an alternative, Aghion, Askenazy, Berman, Cette and Eymard (2008) identify a firm to be constrained if it has failed to repay a trade credit in the previous year.[7] The increased avail-

[6]That is, firms are grouped into supposedly more and less constrained firms. The latter are expected to be able to raise funds for any investment. Hence, investment spending should not turn out to be sensitive to the availability of internal funds. In contrast, the former group of potentially constrained firms is expected to show a positive relationship that reveals the existence of liquidity constraints.

[7]Using French firm-level data, they show that the share of R&D investment over total investment is counter-cyclical without credit constraints, but is less counter-cyclical as firms face tighter credit constraints.

ability 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.[8] They are identified if they report that innovation projects were hampered in some way by the lack of finance.[9] Hajivassiliou and Savignac (2008) employ such a direct survey-based measure and account for simultaneity of financial constraints and innovation. They find that binding financing constraints discourage innovation and at the same time innovative firms are more likely to face binding constraints.

Traditional investment models as well as survey-based studies suffer, however, from difficulties of distinguishing cash flow shocks from demand shocks. Our empirical approach is aimed at tackling this methodological issue. Moreover, firms simultaneously determine their levels of innovation investment, capital investment, dividends, debt payments as well as retentions. That is, the option of investing in innovation competes with alternative uses of funds. We take this into account by performing a 5-equation multivariate analysis. Previous studies do not explicitly estimate equations for all these options, although dynamic programming models of investment and financing behavior do implicitly take alternative uses of funds into account.[10] Finally, we explore the role of innovative capabilities for financial constraints that have been generally paid little attention to.

3 Theoretical Framework and Hypotheses

We draw from a simple model by Howe and McFetridge (1976) and David, Hall and Toole (2000) to explore how innovative capability affects financing constraints for innovation.[11] In this setting, it is assumed that in each planning period firm i has a certain set of ideas for innovation projects.[12] This set of projects is determined by the firm's innovative capability

[8]Innovation surveys are collected in most OECD countries. In Europe they are called the Community Innovation Surveys (CIS). The survey methodology is based on guidelines set out by the Oslo Manual (OECD and Eurostat 2005, first published in 1992).

[9]For studies using this type of indicator, see Canepa and Stoneman 2002, Savignac 2008 and Tiwari et al. 2007.

[10]Dynamic programming models determine optimal investment and financing decisions by maximizing firm value (see Auerbach 1979, Fazzari et al. 1988, and Hall 1995 for an extension to R&D). Grabowski and Mueller (1972) and Gugler (2003) simultaneously investigate the determinants of R&D, capital investment and dividends. Guerard, Bean and Andrews (1987) additionally account for new debt issue.

[11]This supply and demand heuristic has also been used by Hubbard (1998) for investments and by Fazzari et al. (1988) and Carpenter and Petersen (2002) to illustrate financing hierarchies for R&D.

[12]For simplicity, the projects are assumed to be finely divisible so that the resulting marginal rate of return (MRR) schedule is continuous and continuously differentiable.

(IC_i), that is, its ability to generate and pursue new innovation project ideas. The firm ranks these projects according to their expected rate of return in descending order.[13] This results in a downward sloping demand function (D_i) for innovation financing that reflects the marginal rate of return (MRR_i) of firm i. The marginal rate of return depends on the level of innovation expenditure (I_i), on the innovative capability (IC_i) as well as on other firm and industry characteristics (X_i):

$$MRR_i = f(I_i, IC_i, X_i). \tag{1}$$

Profit-maximizing firm i invests in innovation up to the point where the marginal rate of return equals the marginal cost of capital (MCC_i). MCC_i varies with the size of the investment and reflects the opportunity costs of investing funds in innovation. Hence, MCC_i also depends on the expected returns to other uses of available funds such as investment in tangible or financial assets (summarized in $R_i^{e,o}$) as well as on the amount of firms' internal funds (IF_i). In imperfect capital markets costs of external capital are assumed to be higher than those of internal funds as lenders require a risk premium for instance due to information asymmetries. Marginal capital costs are thus also affected by firm characteristics such as creditworthiness (W_i) which depends on collateral as well as capital structure. MCC_i increases with the total amount borrowed. Finally, we assume a pecking order, i.e. firms draw first on internal funds before resorting to external financing.

$$MCC_i = f(I_i, R_i^{e,o}, IF_i, W_i). \tag{2}$$

Figure I illustrates both the demand and the marginal cost function. Equating MRR_i and MCC_i yields the reduced form for optimal investment (I_i^*) in innovation (see Grabowski and Mueller 1972):

$$I_i^* = h(IC_i, R_i^{e,o}, IF_i, X_i, W_i). \tag{3}$$

What happens if additional cash is given exogenously to firms? Deciding upon investment, exogenous cash is not for free due to opportunity costs. If a firm can already finance its optimal investment level I^* fully internally, additional cash has no effect on its innovation investment. A finding that the firm does not increase its investment can either indicate that it faced the same capital costs for both funds before (as on perfect capital markets) or that capital markets are imperfect but the firm does not have additional beneficial innovation

[13] The expected rate of return is derived from the expected benefits less implementation costs.

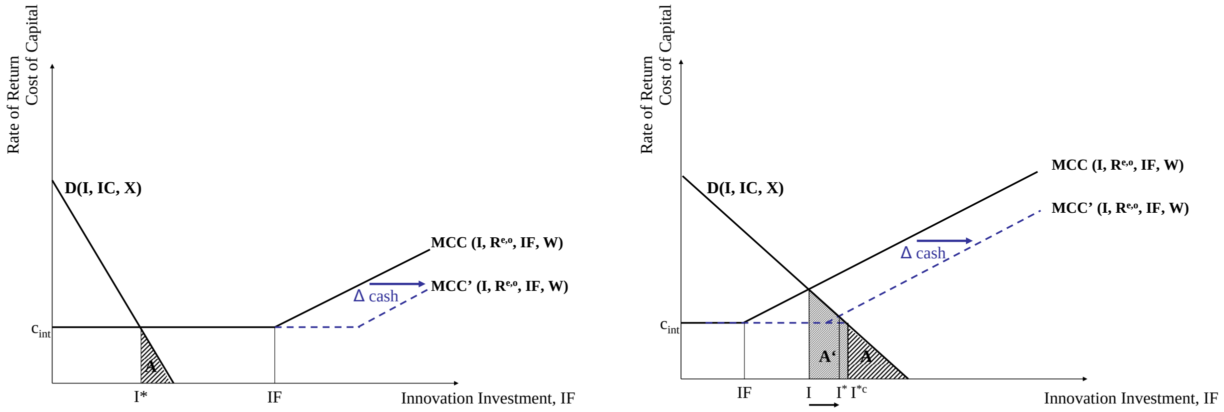
opportunities (at the given internal cost of capital c_{int}). In any case, such a firm can be defined as *financially unconstrained* as it pursues all privately profitable innovation projects at c_{int} (Figure Ia). Area A reflects privately non-profitable innovation potential.[14] If innovation investment is stimulated by exogenous cash flow shocks, we can reject the hypothesis that external and internal capital costs are the same. A positive expansionary effect from additional cash on investment can thus be seen as a result from financing constraints that has curtailed firms' innovation investments at sub-optimal levels I (Figure Ib). I^* reflects the innovation investment that is realized with additional cash. Depending on the amount of cash, it is equal or smaller than $I^{*,c_{int}}$, the optimal investment at internal capital costs.

This setting allows us to derive hypotheses about the interplay of innovative capability, financial resources and financing constraints for innovation. First, we look at innovative capability. Consider two firms A and B, B having a higher innovative capability than A but that are otherwise identical. We assume a firm to have a higher innovative capability if for each rate of return it has a larger or equal number of projects at hand. This implies that for each rate of return the more innovative firm demands a larger or equal *additional* amount of financial resources.[15] The higher B's innovative capability the more likely it is that additional cash leads to an expansionary effect (Figure IIa). If both firms cannot originally finance their innovation from internal funds alone, additional cash increases the innovation investment of both (Figure IIb). The effect, however, is larger for the firm with higher innovative capability if both receive the same amount $\Delta CASH$. This holds as long as the slope of D_B is flatter than the one of D_A. The sum of areas $A+A'$ and $B+B'$ represent the firms' stock of project ideas that render unprofitable given the rate of borrowing c_{ext}, respectively. Additional cash reduces these costs and thus sets free additional projects (Areas A' and B').

Second, Figure III (a) shows how different levels of available internal financing affect the likelihood of financing constraints given a certain innovative capability . Suppose firms A and B have the same innovative capability, but different levels of internal funds ($IF_B > IF_A$). Due to lower internal liquidity, firm A is assumed to also face higher costs of external capital than B. This implies that the expansionary effect is stronger for A even with $\Delta CASH_A = \Delta CASH_B$.

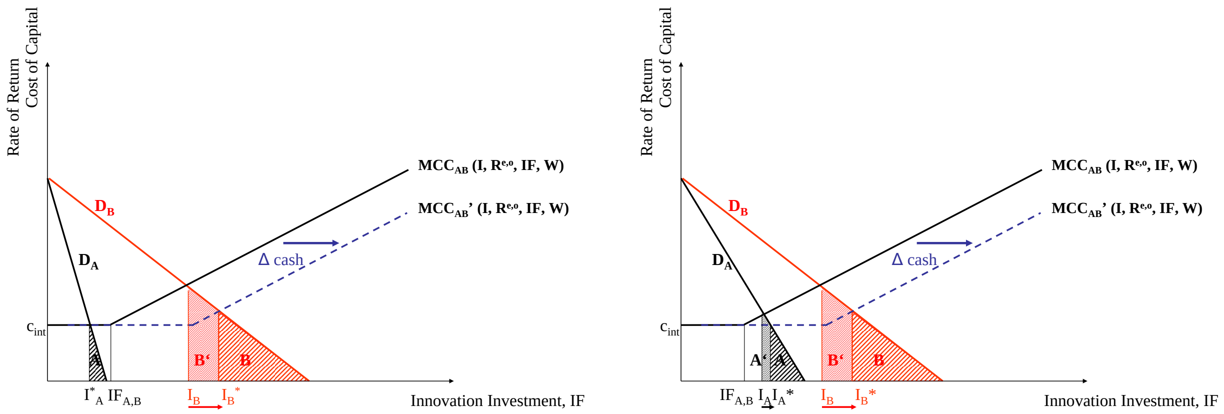
[14] These projects may generate additional social returns that might render them profitable from a welfare point of view.

[15] This assumption assures that i) the two demand curves either have the same intercept or the one of the more innovative firm starts at a higher point, and ii) the demand curve of the more innovative firm exhibits a flatter slope.



(a) unconstrained (b) constrained

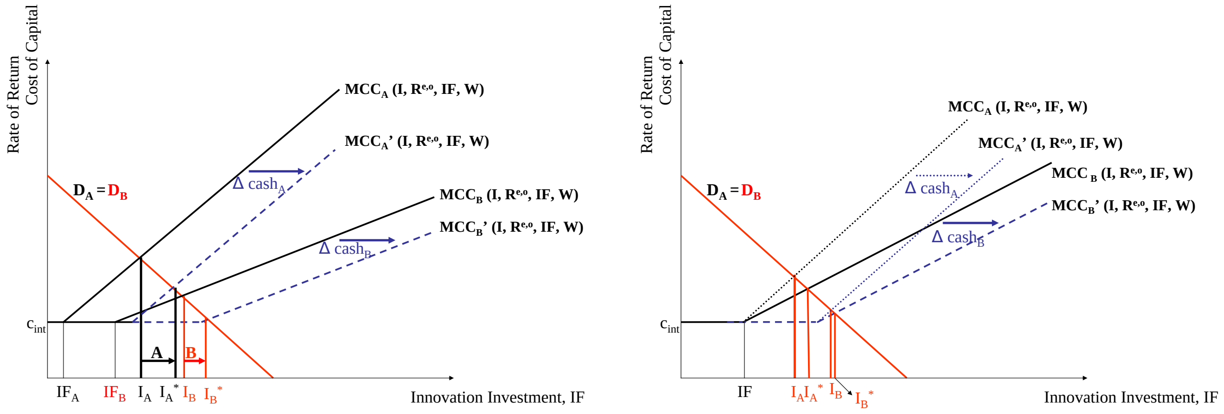
Figure I: Unconstrained versus constrained firm (Hall 2002)



(a) A unconstrained and B constrained (b) both constrained

Figure II: Firms with heterogenous innovative capability (own representation)

In addition to internal funds, the slope of the MCC in the non-horizontal part likewise depends on firm properties that affect the firm's creditworthiness (W_i). For two firms with the same innovative capabilities and comparable levels of internal funds, the expansionary effect is larger for the firm facing the larger gap between c_{int} and c_{ext} (Figure III (b)).



(a) different internal funds

(b) different borrowing rates

Figure III: Homogenous innovative capability, but different (access to) funds

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

Hypothesis 1: Given the same level of internal funds, firms with higher innovative capability should be more likely to be constrained than firms with lower innovative capability.

Hypothesis 2: Given the same level of innovative capability, firms with lower financial resources should be more likely to be constrained.

Hypothesis 3: Firms that face a larger gap between the cost of internal and external capital should be more likely to be financially constrained.

Whether the likelihood of being constrained is larger for firms with low IC and low IF than for firms with high IC and high IF is not clear-cut. It depends on whether lack of internal financing or innovative capability drives financial constraints.

Obviously, some of the assumptions of this basic setting are contestable. This particularly concerns the non-marginal nature of project costs and the information necessary to rank innovation opportunities appropriately. Furthermore, it is assumed that firms always draw upon internal funds first. However, firms may pay out the additional cash to shareholders and raise external capital to leverage the risk to lenders (Jensen and Meckling 1976, Easterbrook 1984, Jensen 1986).[16]

[16] An even "more ideal" test for the degree of financial constraints would be to ask: what would be the amount a firm would invest if capital markets were perfect? If we assume that the marginal costs of capital in case of perfect capital markets are the same as the internal marginal costs of capital in imperfect markets and the amount of additional cash is large enough (exploiting the innovation potential) then the outcome would be the same as above. If the additional cash is not large enough to undertake all beneficial projects, firms would still be constrained. In that case we would underestimate the expansionary effect. But since we only ask wether they would spend additional cash on the different sources and not how much, our effect goes in the same direction as this more ideal test would go.

4 Empirical Implementation

The following analysis makes use of the 2007 wave of the Mannheim Innovation Panel (MIP). The MIP started in 1993 with the aim to provide representative innovation data for policy and research purposes. It is the German part of the European-wide Community Innovation Surveys (CIS) and thus provides internationally comparable data. The target population covers all firms with at least 5 employees in the German business sector.[17] The present study focuses on information of 2,468 firms in manufacturing industries.[18] The sample distribution across industries is presented in Table A.1 in the Appendix.

4.1 Measuring Financing Constraints

Following the concept of an ideal experiment suggested by Hall (2008), the survey requested firms to imagine that they receive additional funds amounting to 10% of the firms' last year's turnover and to indicate how they would spend this money. The following five response options were given of which they could choose one or more: (additional) investment projects, (additional) innovation projects, retention / reserves, payout to shareholders or repayment of debt. In this design, one can estimate the treatment effect by comparing the innovation activities of each firm before and after the cash receipt. In our case this is measured by whether the firm would additionally invest in innovation compared to the current situation. A firm is thus considered to be financially constrained if it would invest additional funds in innovation projects ($CON = 1$, otherwise $CON = 0$). The conceptual set-up allows us to estimate not only the likelihood of being constrained but also the degree to which these constraints affect the firms' innovation investments. We distinguish three different degrees: $TYPE = 0/1/2$ if the firm indicates that it would not / partially / exclusively invest in additional innovation projects. Thus, $TYPE$ is an ordinal variable that increases the more binding the firm's financial constraints for innovation are. The variables CON and $TYPE$ represent the main dependent variables in our empirical study. Taking into account that innovation competes with other usages, we additionally define a set of binary indicators for

[17] The survey is conducted annually by the Centre for European Economic Research (ZEW), infas Institut für Sozialforschung and ISI Fraunhofer Institute on behalf of the German Federal Ministry of Education and Research. A detailed description of the survey data can be found in Peters (2008).

[18] 630 observations were deleted from the original data-set due to item non-response or outlier correction.

each of the alternative response options and estimate a simultaneous multivariate probit model.

The approach presented in this study is obviously different from traditional (R&D) investment equations (see Bond and Van Reenen 2007 for a survey). Accelerator and error-correction models represent two frequently used approaches. Since cash flow may be correlated with future investment opportunities, the main critique on these reduced-form investment models is that estimated cash flow effects cannot be interpreted without ambiguity. Excess sensitivity tests in structural models, on the other hand, are justified formally as Tobin's q in the popular Q model summarizes all the information about expected future profitability that is relevant for the current investment decision. The Q model, however, requires strong assumptions, and the dissatisfaction with the empirical performance has led to the development of structural models such as the Euler equation approach. This approach relaxes some of the assumptions underlying the Q model. It particularly avoids both parameterization of the expectations formation process and the use of share price data. In spite of important theoretical advantages of structural investment models in testing for the presence of financial constraints, the empirical value of Euler equations has been questioned for instance by Bond and Van Reenen (2007). They argue that the advantage of structural models compared to reduced form models should not be overstated as the former "are based on extreme simplifying assumptions, and are frequently rejected when subjected to mild empirical testing" (p. 4422).[19]

Our approach attempts to address these concerns by employing a direct constraint measure in a reduced form regression. We regard the reduced form as "an empirical approximation to some complex underlying process that has generated the [survey] data" (see Bond and Van Reenen 2007, p. 4443). Another difference compared to accelerator and error-correction models is that the hypothetical exogenous cash increase is by definition not driven by future market prospects. Due to the direct measurement of financial constraints, the estimation equation departs from the ones used in accelerator and error-correction models. The binary dependent variable CON represents an increase (or no increase) in investment instead of measuring the *amount* of additional investment. The ordinal dependent variable TYPE

[19] See for example Hall (1995) and Harhoff (1998) for empirical Euler R&D-investment equations providing weak and instable results that often do not correspond to theoretical predictions.

contains a bit more information by measuring the degree to which financial constraints affects innovation, i.e. whether firms would not/partially/exclusively invest the additional cash in innovation. In both cases the results are thus not directly comparable to traditional investment models.

4.2 Innovative Capability and Internal Financing

According to our hypotheses financing constraints are a function of firm liquidity *($M \sim Money$)* and innovative capability *($B \sim Brain$)*. We distinguish between 6 types of firms that differ in terms of their innovative capability 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). A firm's ability to generate ideas for innovation depends to a large extent on the knowledge capital of its employees. This can be measured through formal qualification levels or through knowledge acquired by training. Hence, we use information on the firm's share of highly qualified personnel and its expenditure for training of their employees. A firm is considered to have a high innovative capability (B_H) if either the share of highly qualified personnel or the expenditure on training per employee is larger than the 80th percentile (in 2006). Other studies measure innovative capability also by the firm's R&D expenditure or past innovation success. As our study also involves firms that are not (yet) engaged in R&D and innovation, we prefer the more general definition above.[20] The profit margin (earnings before taxation as a share of total sales in 2006) is used to measure the availability of internal funds. Originally the profit margin is an ordinal variable with eight categories that we grouped into three dummy variables (see Table A.2 in the Appendix). Firms are assumed to have a low financial endowment *(M_L)* if the profit margin is smaller than zero. If the ratio is larger than zero, but smaller than 7%, the firm exhibits a medium financial background (M_M). Finally, M_H equals one if the firm's ratio is at least 7%. By interacting financial resources and innovative capability we get 6 groups of firms that differ in their *Resource Endowments.*

[20] We test the sensitivity of our results by using either alternative cut-off-points and pre-period innovation success or firms' share of R&D personnel. The results of this sensitivity analysis are presented in Table A.4.

Table I: Resource endowments

Innovative Capability \ Financial Resources	*high*	*medium*	*low*
high	$B_H M_H$	$B_H M_M$	$B_H M_L$
low	$B_L M_H$	$B_L M_M$	$B_L M_L$

4.3 Access to External Finance

Being a family-owned company *(FAMCOM)*, that is the majority of stakes belongs to members of one family, may affect financing conditions. On the one hand, family-owned firms may have an advantage in external capital cost since they more often have a close and long-established relationship with their house bank. On the other hand, recent empirical evidence has shown that family-owned firms tend to avoid dependency on external lenders (Peters and Westerheide 2011). Thus, they perceive themselves as constrained and postpone or cancel projects if these projects cannot be funded by internal funds. Capital intensity is measured by the value of firms' tangible assets per employee in 2006 *(KAPINT)* and reflects firms' overall collateral value. We further complemented our survey data with the firms' credit rating indices that we assume to reflect cost of external capital *(RATING)*. The credit rating is an index between 100 and 600, 100 representing the best rating.[21] Firms that are part of a company group *(GROUP)* may benefit from intra-group financing flows that represent an alternative outside-firm financing channel.

4.4 Control Variables

The derivation of our hypotheses is based on the assumption that the firms only differ in innovation capacity, internal funds or access to external finance. To take into account that this is not true in the data, we include a set of control variables. Firm age *(AGE)* is measured in years since founding, and firm size *(SIZE)* is measured by the number of employees. Since the distributions of *SIZE* and *AGE* are highly skewed we take logs of both variables. Moreover, we include the firms' product life cycle patterns *(PLC)* as a shorter product life cycle may increase the pressure to develop new products and hence increases the need for resources. Shorter product life cycles may also imply shorter periods for generating returns from prior

[21] The credit rating index is a standardized measure provided by Creditreform, Germany's largest credit rating agency.

product innovations. We account for the amount of additional funds that firms would receive ($CASH$) and construct five categories for $CASH$ on the basis of the 20, 40, 60, and 80th percentile of the distribution. We further include a regional dummy that indicates whether the firm is located in East Germany ($EAST$) to control for regional differences.[22] To take into account the competitive environment of the firm we employ a Herfindahl-index of industry sales concentration published by the German Monopolies Commission ($COMP$). Finally, we cannot rule out that the job function of the respondent may effect the response. We distinguish between respondents from the general management (CEO), R&D ($R\&D\_DEP$), financial (FIN_DEP), sales ($SALES\_DEP$), and other departments ($OTHER\_DEP$).

4.5 Descriptive Statistics

About 36% of the firms in our sample are financially constrained as can be gathered from the summary statistics in Table II. Only 5%, however, would invest the full amount of additional cash in innovation while the large majority would only partially invest in innovation. 68% of the firms would allocate at least part of the money to general investments, 44% would pay out the money to shareholders, 21% would retain the cash, and 44% would rather serve debt. When looking at our main covariates of interest, we see that most firms (43%) were classified as having a rather low innovative capability while being in a solid financial situation ($B_L M_M$). 18% of firms with low innovative capability are even in good financial situation ($B_L M_H$). 33% of all firms were defined as having a high innovative capability. 4% of those firms have a negative profit-turnover-ratio ($B_H M_L$). 18% exhibit a solid financial background ($B_H M_M$), and 11% are financially well endowed ($B_H M_H$). The average and median amount of $CASH$ firms would receive is 10.12 million and 611,000 €, respectively. In the first class, the mean of $CASH$ is about 58,000 €, in class 2 about 206,600 €, in class 3 about 645,000 €, in class 4 about 2.1 million € and 47 million € in class 5.[23] When looking at the firm characteristics of constrained and unconstrained firms, interesting differences can be inferred from the test in differences in means. As expected, constrained firms are less capital-intensive, face shorter

[22] Due to extensive R&D subsidy programs targeting East German firms, these firms were found to face less financing constraints in the 1990s and early 2000s (Czarnitzki 2006).

[23] The maximum hypothetical payment of 4.4 billion € is no data error but refers to a large company in the energy sector. We ran all our models with this company excluded from the data which did not significantly alter the results.

product life cycles, and are less frequently located in East Germany. At first glance it is surprising that they are larger, do not differ in terms of age, and have a better credit rating. Moreover, we observe that in the group of constrained firms, the share of firms with high innovative capability is higher. This is valid irrespective of their financial background.[24]

[24]See Table A.5 in the Appendix for cross-correlations between the variables.

Table II: Summary statistics

		Manufacturing (2,468 obs.)						$CON = 0$	$CON = 1$	
Variable	**Var. type**	**Description**	**Median**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**Mean**	**Mean**	**t-test**
dependent variables:										
CON	dummy	[0/1]	0	0.360	0.480	0	1			
$TYPE$	categorical	[0/1/2]	0	0.378	0.521	0	2			
resource endowment indicators:										
$B_H M_L$	dummy	[0/1]	0	0.039	0.193	0	1	0.030	0.054	***
$B_H M_M$	dummy	[0/1]	0	0.179	0.383	0	1	0.159	0.213	***
$B_H M_H$	dummy	[0/1]	0	0.111	0.315	0	1	0.092	0.145	***
$B_L M_L$	dummy	[0/1]	0	0.071	0.257	0	1	0.073	0.068	
$B_L M_M$	dummy	[0/1]	1	0.425	0.494	0	1	0.460	0.363	***
$B_L M_H$	dummy	[0/1]	0	0.175	0.380	0	1	0.185	0.157	*
main control variables:										
$SIZE$	continuous	headcount	48	351.996	2,534.748	1	72,900	245.196	542.356	***
AGE	continuous	years	16	21.065	21.560	1	590	20.442	21.709	
$CASH$	continuous	mio.€	0.611	10.120	104.717	0.002	4425.6	6.911	15.841	**
$FAMCOM$	dummy	[0/1]	1	0.666	0.472	0	1	0.654	0.687	*
$GROUP$	dummy	[0/1]	0	0.331	0.471	0	1	0.310	0.368	***
$KAPINT$	continuous	mio.€/ empl.	0.024	0.089	0.309	0	8.589	0.109	0.054	***
$RATING$	continuous	[1-6] (1 = best)	2.18	2.273	0.653	1	6	2.297	2.230	**
PLC	continuous	years	12.51	18.814	21.695	1	300	20.256	16.244	***
$EAST$	dummy	[0/1]	0	0.307	0.461	0	1	0.323	0.277	**
CEO	dummy	[0/1]	1	0.641	0.480	0	1	0.642	0.640	
$R\&D\_DEP$	dummy	[0/1]	0	0.062	0.242	0	1	0.047	0.090	***
FIN_DEP	dummy	[0/1]	0	0.157	0.364	0	1	0.170	0.133	**
$SALES\_DEP$	dummy	[0/1]	0	0.013	0.115	0	1	0.013	0.015	
$OTHER\_DEP$	dummy	[0/1]	0	0.063	0.243	0	1	0.063	0.064	
$PRIVATE$	dummy	[0/1]	0	0.123	0.328	0	1	0.145	0.083	***
$PUBLIC$	dummy	[0/1]	0	0.038	0.192	0	1	0.038	0.039	**
$LIMITED$	dummy	[0/1]	1	0.835	0.371	0	1	0.812	0.877	***

***(**,*) indicate a significance level of 1% (5%, 10%).

5 Econometric Analysis

5.1 Probit and Ordered Probit Models

As shown in section 3, the degree of financing constraints y^* depends on financial resources M, innovative capability B, other observable firms characteristics Z as well as non-observable factors ε (for simplicity, we suppress firm subscripts i):

$$y^* = \beta_0 + \beta_1 B_H M_L + \beta_2 B_H M_M + \beta_3 B_H M_H + \beta_4 B_L M_L + \beta_5 B_L M_M + \sum_l \beta_l Z_l + \varepsilon. \quad (4)$$

Z includes the variables defined in sections 4.3 and 4.4 and a set of 14 industry dummies. Since we do not directly observe the degree of constraint, we first estimate the likelihood of being financially constrained by using a probit model. This can be written as

$$P(CON = 1|\mathbf{x}) = I(y^* > 0) = \Phi(\mathbf{x}\beta), \quad (5)$$

with the row vector $\mathbf{x}$ comprising the interaction terms and Z. According to Hypothesis 1 (H1) formulated in section 3, we expect that $\beta_1 > \beta_4$, $\beta_2 > \beta_5$, and $\beta_3 > 0$. Furthermore, we expect for firms exhibiting the same innovative capability, like B_H, that $\beta_1 > \beta_2 > \beta_3$ (H2). Finally, Hypothesis 3 (H3) suggests a positive coefficient of the variable capturing creditworthiness as $RATING$ ranges from 1 to 6 with 6 being the worst rating. Contrarily, capital intensity and group membership should negatively impact the likelihood of being constrained. In order to account for heterogeneity and correlation among firms, estimated standard errors are heteroscedasticity-consistent and clustered by industries and region. In a second step, we proxy the degree of constraints by our categorial variable *(TYPE)* and estimate ordered probit models.

Table III provides the estimation results of 3 different specifications of the probit model on the likelihood of facing financial constraints. Model 1 presents the base specification including variables for innovative capability and internal finance as well as control variables. In Model 2 we add variables reflecting access to external finance ($FAMCOM$, $GROUP$, $KAPINT$ and $RATING$). We enhance the specification by including classes for $CASH$ in model 3 (the lowest category serves as the reference category).

The marginal effects of the interaction terms for firms with a high innovative capability ($B_H M_L$, $B_H M_M$, $B_H M_H$) are all significantly positive, unlike for firms with low innovative capability (B_LM_L and B_LM_M, with B_LM_H being the reference category). We test the three inequality relations contained in H1 individually as well using a joint test. The results clearly confirm H1: Given the same level of internal funds, firms with a high innovative capability are more likely to be constrained than firms with low innovative capability.

Among firms with high innovative capability, those having low financial resources (B_HM_L) are more likely to be constrained than firms that have a solid financial background (B_HM_M). Tests confirm that the marginal effect is indeed significantly larger for firms with B_HM_L. However, Hypothesis 2 is only partly confirmed. We do not observe a monotonic relationship as we would have expected. That is, there is no significant difference between firms with B_HM_M and B_HM_H. Furthermore it turns out that firms with low financial resources and low innovative capability (B_LM_L) are not more likely to be constrained than firms having a rich financial endowment and low innovative capability. In addition, it was not clear from the theory whether B_LM_L is more or less constrained than B_HM_H. The empirical evidence convincingly shows that firms belonging to B_HM_H have a higher likelihood of facing constraints. Altogether, these results imply that innovative capability and not solely financial resources drives financing constraints for innovation.

Accounting for access to external finance, surprisingly we do not find any robust impact of $RATING$ across specifications. The multivariate probit model will shed some light on this variable in the firm's decision-making process. The variables $KAPINT$ and $GROUP$ show the expected signs. A higher capital intensity significantly reduces the likelihood of facing binding constraints. Being part of a group also exerts a negative, yet insignificant, effect. Family-owned firms seem to be more willing to spend this additional cash on innovation than non-family-owned firms. These four variables are jointly significant and thus confirm H3. With respect to the control variables no effects were found for the duration of the product life cycle and firms' age.[25] Finally, we detect differences in response patterns of the financial department and sales-managers from those of CEOs and R&D managers.

As the firms receive different amount of hypothetical cash, we include the cash classes in specification 3. The results show that the positive effect of $CASH$ is increasing with the size

[25]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. However, the survey is representative for firms with at least 5 employees. This implies that a large proportion of very young firms does not belong to the target population.

of the hypothetical payment. The effect doubles from class 3 to class 4 indicating a critical size of the payment of about roughly 1 million € that significantly increases the likelihood of new innovation projects. Ideally, we would like to disentangle size from cash effects. However, $CASH$ is measured as percentage of turnover and turnover correlates with firm size. Thus, we have to admit that we cannot interpret the effects from $CASH$ as pure cash-effects and are furthermore faced with high multicollinearity. Therefore, we leave out $CASH$ in the subsequent models. Finally it should be noted that we test for normality (Verbeek 2000, p.168). The test statistics show that normality cannot be rejected in any of our models (e.g. p-value = 0.473 in Model 2 of Table III).

Table IV shows the results of 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 and standard errors of the likelihood of the different outcomes of $TYPE$. The ordered model by and large confirms our previous results.[26] Regarding the degree of constraints, firms with a high innovative capability but low financial resources exhibit a likelihood of being constrained in terms of outcome 1 that is 18 percentage points higher than for the reference group. For outcome 2 the effect of 3 percentage points for $B_H M_L$ may appear small. However, given that only 5% of the firms in the sample would invest the full amount the effect is comparatively large.

[26]It should be noted that the condition $\mu_2 > \mu_1 > 0$ necessary for all probabilities to be positive is fulfilled.

Table III: Probit models on the likelihood of being constrained *(CON) (2,468 obs.)*

	Model 1		**Model 2**		**Model 3**	
Variable	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**
$B_H M_L$ (β_1)	0.196***	(0.062)	0.214***	(0.060)	0.226***	(0.061)
$B_H M_M$ (β_2)	0.096***	(0.035)	0.098***	(0.034)	0.095***	(0.034)
$B_H M_H$ (β_3)	0.135**	(0.056)	0.136**	(0.055)	0.136***	(0.055)
$B_L M_L$ (β_4)	0.018	(0.051)	0.022	(0.053)	0.026	(0.053)
$B_L M_M$ (β_5)	-0.038	(0.024)	-0.040	(0.025)	-0.042*	(0.025)
$ln(SIZE)$	0.050***	(0.007)	0.051***	(0.007)	0.016	(0.014)
$ln(AGE)$	0.005	(0.014)	0.003	(0.014)	-0.001	(0.013)
$ln(PLC)$	-0.015	(0.013)	-0.015	(0.013)	-0.014	(0.013)
$EAST$	-0.041**	(0.019)	-0.032	(0.020)	-0.024	(0.020)
FIN_DEP	-0.114***	(0.027)	-0.107***	(0.027)	-0.114***	(0.027)
$R\&D\_DEP$	0.035	(0.042)	0.041	(0.041)	0.048	(0.040)
$SALES\_DEP$	-0.077*	(0.038)	-0.073*	(0.039)	-0.084**	(0.039)
$OTHER\_DEP$	-0.045	(0.039)	-0.043	(0.039)	-0.048	(0.039)
$COMP$	0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
$FAMCOM$ (β_{15})			0.037*	(0.019)	0.037*	(0.019)
$GROUP$ (β_{16})			-0.015	(0.031)	-0.032	(0.033)
$KAPINT$ (β_{17})			-0.113**	(0.056)	-0.134**	(0.059)
$RATING$ (β_{18})			-0.018	(0.015)	-0.012	(0.015)
$ln(CASH)_{c2}$					0.103**	(0.041)
$ln(CASH)_{c3}$					0.106***	(0.042)
$ln(CASH)_{c4}$					0.216***	(0.053)
$ln(CASH)_{c5}$					0.227***	(0.072)
Log-likelihood	-1,493.475		-1,489.708		-1,480.134	
McFadden's R^2/Count R^2	0.073/0.662		0.076/0.657		0.082/0.665	
McKelvey & Zavoina's R^2	0.154		0.164		0.177	
AIC / BIC	1.234/-16,064.478		1.234/-16,040.768		1.229/-16,028.671	
Joint sig. ind. dummies	$\chi^2(14) = 641.23^{***}$		$\chi^2(14) = 370.10^{***}$		$\chi^2(14) = 392.72^{***}$	
H_1: $\beta_1 > \beta_4$	$p = 0.011^{**}(^{\diamond\diamond})$		$p = 0.007^{***}(^{\diamond\diamond})$		$p = 0.006^{***}(^{\diamond\diamond})$	
H_1: $\beta_2 > \beta_5$	$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$	
H_1: $\beta_3 > 0$	$p = 0.014^{**}(^{\diamond\diamond})$		$p = 0.012^{**}(^{\diamond\diamond})$		$p = 0.012^{**}(^{\diamond\diamond})$	
H_2: $\beta_1 > \beta_2$	$p = 0.030^{**}(^{\diamond})$		$p = 0.012^{**}(^{\diamond\diamond})$		$p = 0.007^{***}(^{\diamond\diamond})$	
H_2: $\beta_1 > \beta_3$	$p = 0.099^{*}(^{-})$		$p = 0.052^{*}(^{-})$		$p = 0.037^{**}(^{\diamond})$	
H_2: $\beta_2 > \beta_3$	$p = 0.809(^{-})$		$p = 0.799(^{-})$		$p = 0.817(^{-})$	
H_3: joint sig. test of $\beta_{15} - \beta_{18}$	*n.i.*		$\chi^2(4) = 8.92^{*}$		$\chi^2(4) = 10.18^{**}$	

All models 1-3 contain a constant and industry dummies. ***(**,*) indicate a significance level of 1% (5%, 10%). Standard errors are robust and clustered by industries and East vs. West Germany (30 clusters). H1 tests Hypothesis 1 using one-sided tests. ***(**,*) indicate 1% (5%, 10%) significance level of an individual test for each of the three hypotheses in H1. $^{\diamond\diamond\diamond}$($^{\diamond\diamond}$,$^{\diamond}$) mark the significance level of a joint test with Bonferroni-adjusted significance levels α/n. For the joint test an overall α of 1% (5%, 10%) implies significance levels of 0.003 (0.017, 0.033) for each of the three hypotheses in H1. Analog for H2. ($^{-}$) indicates non-significance.

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

	Model		Outcome 0		Outcome 1		Outcome 2	
Variable	**Coef.**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**
$B_H M_L$ (β_1)	0.556***	(0.128)	-0.213***	(0.048)	0.183***	(0.038)	0.030***	(0.011)
$B_H M_M$ (β_2)	0.284***	(0.080)	-0.108***	(0.031)	0.097***	(0.028)	0.011***	(0.004)
$B_H M_H$ (β_3)	0.409***	(0.120)	-0.156***	(0.044)	0.138***	(0.038)	0.018***	(0.007)
$B_L M_L$ (β_4)	0.044	(0.129)	-0.023	(0.047)	0.021	(0.042)	0.002	(0.004)
$B_L M_M$ (β_5)	-0.086	(0.060)	0.028	(0.021)	-0.025	(0.019)	-0.002	(0.002)
$ln(SIZE)$	0.114***	(0.015)	-0.041***	(0.006)	0.037***	(0.005)	0.003***	(0.001)
$ln(AGE)$	0.018	(0.039)	-0.007	(0.014)	0.006	(0.013)	0.001	(0.001)
$ln(PLC)$	-0.039	(0.033)	0.015	(0.012)	-0.013	(0.011)	-0.001	(0.001)
$EAST$	-0.110*	(0.057)	0.040*	(0.021)	-0.037*	(0.019)	-0.003*	(0.002)
FIN_DEP	-0.322***	(0.077)	0.112***	(0.025)	-0.104***	(0.024)	-0.008***	(0.002)
$R\&D\_DEP$	0.080	(0.089)	-0.030	(0.034)	0.028	(0.031)	0.003	(0.003)
$SALES\_DEP$	-0.198*	(0.103)	0.070**	(0.035)	-0.065**	(0.032)	-0.005**	(0.002)
$OTHER\_DEP$	-0.071	(0.111)	0.026	(0.040)	-0.024	(0.037)	-0.002	(0.003)
$COMP$	0.001	(0.001)	-0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
$FAMCOM$ (β_{15})	0.083	(0.051)	-0.031*	(0.019)	0.029*	(0.017)	0.003*	(0.001)
$GROUP$ (β_{16})	0.020	(0.072)	-0.010	(0.026)	0.009	(0.024)	0.001	(0.002)
$KAPINT$ (β_{17})	-0.343**	(0.158)	0.127**	(0.058)	-0.116**	(0.053)	-0.011*	(0.005)
$RATING$ (β_{18})	-0.034	(0.039)	0.013	(0.014)	-0.012	(0.013)	-0.001	(0.001)
μ_1	1.243	(0.320)						
μ_2	3.112	(0.327)						
Log-likelihood	-1,663.758							
McFadden's R^2 / Count R^2	0.075/0.657							
McKelvey & Zavoina's R^2	0.160							
AIC / BIC	1.377/-15,682.209							
Joint sig. ind. dummies	$\chi^2(14) = 277.87^{***}$							
H_1: $\beta_1 > \beta_4$	$p = 0.002^{***}(^{\diamond\diamond\diamond})$							
H_1: $\beta_2 > \beta_5$	$p = 0.000^{***}(^{\diamond\diamond\diamond})$							
H_1: $\beta_3 > 0$	$p = 0.001^{***}(^{\diamond\diamond\diamond})$							
H_2: $\beta_1 > \beta_2$	$p = 0.011^{**}(^{\diamond\diamond})$							
H_2: $\beta_1 > \beta_3$	$p = 0.108(^{-})$							
H_2: $\beta_2 > \beta_3$	$p = 0.911(^{-})$							
H_3: joint sig. test of $\beta_{15} - \beta_{18}$	$\chi^2(4) = 7.67$ ($p = 0.105$)							

Notes: see Table III.

5.2 Multivariate Probit Model

Certainly, firms have to choose between alternatives of use for the money. The decision for each of the alternatives might be influenced by common unobservable factors such as firm-specific interest rates or the risk attitude of managers. Estimating a single probit equation whether to additionally invest in innovation then provides consistent estimates but a simultaneous estimation that takes into account the full covariance structure is in general more efficient. To account for the rivalry in the usage of additional cash, we therefore additionally estimate a 5-equation multivariate probit model:

$$\begin{aligned} y_m^* &= \mathbf{x}_m \beta_m + \varepsilon_m, \quad m = 1, \ldots, 5. \\ y_m &= I(y_m^* > 0), \quad m = 1, \ldots, 5. \\ \epsilon &= (\varepsilon_1, \ldots, \varepsilon_5)' \sim N(0, \Sigma) \end{aligned} \tag{6}$$

m represents the decisions to invest in physical capital, in innovation, to build reserves, to payout to shareholder or to repay debts. The variance-covariance matrix Σ has values of 1 on the diagonal due to normalization and correlations $\rho_{jk} = \rho_{kj}$ as off-diagonal elements. The log-likelihood function is then given by:

$$lnL(\beta_1, \ldots, \beta_5, \Sigma; y|\mathbf{x}) = \sum_{i=1}^{N} ln\Phi_5 \left(\left(q_{i1}\mathbf{x}_{i1}\beta_1, \ldots, q_{i5}\mathbf{x}_{i5}\beta_5 \right); \Omega \right), \tag{7}$$

where $q_{im} = 2y_{im} - 1$. The matrix Ω has values of 1 on the diagonal and $\omega_{jk} = \omega_{kj} = q_{ij}q_{ik}\rho_{jk}$ for $j \neq k$ and $j, k = 1, \ldots, 5$ as off-diagonal elements. Φ_5 denotes the joint normal distribution of order 5. The expression for lnL thus involves a 5-dimensional integral that does not have a closed form. It can be evaluated numerically through simulation. We employ the Maximum Simulated Likelihood Method using the GHK simulator (Geweke 1989, Hajivassiliou and McFadden 1998, and Keane 1994), for a detailed description of simulation methods we also refer to Train (2009). We use the user-written command cmp in Stata to estimate the multivariate probit model (see Roodman 2009).[27] The MSL estimator is consistent if the number of draws R rises with N. It is also efficient if R rises faster than $\sqrt{N}$. Furthermore, the simulation bias is negligible when the ratio of the number of draws to $\sqrt{N}$ is sufficiently large (Hajivassiliou and Ruud 1994). We set the number of draws to $2\sqrt{N}$. The simulation

[27] Cmp stands for conditional mixed process. It is a very general command encompassing a broad range of limited dependent variable models, and it allows mixing of these models in multi-equation systems. It differs in a few technical aspects from the user-written command mvprobit in Stata, for more details see Roodman (2009). One virtue of the command is the straightforward calculation of marginal effects.

method requires to draw random variables from an upper-truncated normal distribution. We employ draws based on Halton sequences as they are more effective for simulated MSL estimation than pseudo-random draws (Train 2009).

Table V presents the results from the multi-equation probit model and Table A.3 in the Appendix depicts the estimated correlation coefficients. The table reveals significant correlations between most of the error terms indicating that the equations should indeed be estimated simultaneously. We enrich the specification by including firms' legal form (*PUBLIC* and *LIMITED*, *PIVATE* serves as the reference category) as it may affect payouts to shareholders, for example. The findings for investing in additional innovation projects remain nearly unchanged. Interestingly, our main variables of interest show a fundamentally different pattern in the decision to invest in physical capital. Having a low innovative capability leads to a higher likelihood of choosing additional investments, the effect being highest for $B_L M_L$. Firms with high innovative capability and low financial resources have a lower likelihood of using the additional money for building reserves than other firms. The type of firms that were most likely to invest the additional cash in innovation turn out least likely to build reserves or to pay out cash. The results from equation 4 illustrate that all firms are less likely to distribute the cash to their shareholders than the reference group of firms that have a low innovative capability and rich financial resources. Unlike the choice for innovation, the decision to serve debt is to a large extent driven by the financial background. For both, high and low innovative capability, the likelihood of serving debt rises with decreasing liquidity. That is, we observe the largest effects for $B_L M_L$ and $B_H M_L$. This is in line with the results found for $RATING$. Firms with a worse $RATING$ have a higher probability of serving debt. These firms seems to give priority to consolidating their financial reputation before investing in new projects. Interestingly, the financial department turns out to be more willing to pay out the cash or to pay back debt than CEOs. Moreover, especially public but also limited firms are more likely to distribute cash to their shareholders while being less likely to reduce debt. Estimates for firms belonging to a group suggest that they are generally less constrained: They are less likely to pursue additional investment projects and have a lower propensity to pay back debts.

Table V: Multivariate probit model on all response options (2,468 obs.)

	Equ. 1 Investment		Equ. 2 Innovation		Equ. 3 Reserves		Equ. 4 Payout		Equ. 5 Serv. Debt	
Variable	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**
$B_H M_L$	-0.002	(0.053)	0.219***	(0.060)	-0.177***	(0.053)	-0.104***	(0.030)	0.159***	(0.058)
$B_H M_M$	0.003	(0.033)	0.098***	(0.036)	0.112***	(0.036)	-0.092***	(0.022)	0.057	(0.036)
$B_H M_H$	-0.030	(0.038)	0.145***	(0.042)	0.079*	(0.041)	-0.074***	(0.026)	-0.035	(0.041)
$B_L M_L$	0.067*	(0.040)	0.017	(0.046)	-0.001	(0.046)	-0.065**	(0.029)	0.257***	(0.043)
$B_L M_M$	0.039	(0.028)	-0.045	(0.029)	0.061**	(0.029)	-0.073***	(0.022)	0.115***	(0.030)
$ln(SIZE)$	0.036***	(0.008)	0.052***	(0.008)	-0.004	(0.009)	-0.010	(0.007)	0.009	(0.009)
$ln(AGE)$	-0.010	(0.013)	0.001	(0.014)	-0.014	(0.014)	-0.017	(0.011)	-0.005	(0.015)
$ln(PLC)$	-0.012	(0.011)	-0.014	(0.011)	-0.001	(0.011)	0.011	(0.009)	0.016	(0.011)
$EAST$	0.087***	(0.021)	-0.028	(0.022)	-0.037	(0.023)	-0.085***	(0.017)	0.029	(0.024)
FIN_DEP	-0.020	(0.030)	-0.107***	(0.028)	0.003	(0.031)	0.049*	(0.026)	0.064**	(0.032)
$R\&D\_DEP$	0.019	(0.041)	0.042	(0.044)	-0.018	(0.044)	0.065*	(0.039)	-0.040	(0.045)
$SALES\_DEP$	-0.002	(0.038)	-0.075**	(0.036)	0.107***	(0.041)	0.013	(0.033)	0.047	(0.041)
$OTHER\_DEP$	0.019	(0.040)	-0.038	(0.040)	-0.096**	(0.041)	0.039	(0.037)	0.021	(0.044)
$COMP$	0.001**	(0.001)	0.001	(0.001)	-0.001	(0.001)	0.001	(0.001)	-0.001	(0.001)
$FAMCOM$	0.031**	(0.023)	0.035	(0.023)	0.034**	(0.024)	-0.039**	(0.020)	0.043*	(0.024)
$GROUP$	-0.091***	(0.025)	-0.020	(0.025)	-0.014	(0.026)	0.116***	(0.022)	-0.082***	(0.026)
$KAPINT$	-0.064	(0.040)	-0.130*	(0.077)	-0.098*	(0.050)	0.036*	(0.031)	0.083**	(0.038)
$RATING$	-0.025	(0.015)	-0.022	(0.017)	-0.022	(0.017)	-0.021	(0.014)	0.075***	(0.018)
$LIMITED$	-0.073**	(0.029)	0.070**	(0.032)	0.088***	(0.032)	0.147***	(0.020)	-0.116***	(0.033)
$PUBLIC$	-0.132**	(0.066)	-0.033	(0.062)	0.163***	(0.063)	0.281***	(0.074)	-0.022	(0.064)
Log-likelihood					-7,159.489					
Joint sig. ind. dummies					$\chi^2(70) = 176.20^{***}$					

***(**,*) indicate a significance level of 1% (5%, 10%). The model contains a constant and industry dummies.

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

5.3 Robustness Checks

The previous sections pointed out the important role of innovative capability for financing constraints. Admittedly, we cannot observe innovative capability directly. To test the robustness of our results, we employ alternative proxies for innovative capability. First, we measure innovative capability by the same variables but use different cut-off-points (mean, median and 90th percentile of both highly qualified personnel and expenses for training of employees) or measure it relative to the respective industry distribution. The results are robust within a broad range of cut-off-definitions, as can be gathered from Table A.4 in the Appendix. Second, we employ three alternative variables to define innovative capability. We begin with using only the share of highly qualified personnel (not accounting for training). Next, we test a stricter definition of innovation-related human capital by using the share of R&D employees. For these two checks the original 80% cut-off-point is applied. Finally, we define innovative capability based on successful innovation projects in the past. More precisely, we observe if the firm has introduced at least one new product to the market in the pre-survey period. Table VI summarizes the results from this exercise for our main variables of interest. Hypothesis 1 is confirmed. As before, we also find $\beta_1 > \beta_2$. However, support for $\beta_1 > \beta_3$ is only given if we define innovative capability based on past innovation success.

Another concern which may arise is that the results of the quasi-experiment depend on the fact whether a firm was already engaged in innovation activities. We estimate a two-stage selection model for both CON and $TYPE$. The first stage describes whether the firm has been innovative in the past two years ($INNO$).[28] The selection model hinges upon at least one valid exclusion restriction. We expect the firms' export intensity ($EXINT$) and the diversification of its product portfolio ($DIVERS$) to affect the likelihood to innovate, while it should not impact the likelihood to face financial constraints. Hence, we use both variables as exclusion restriction in the first stage.[29] From Table VII we see that $DIVERS$ and $EXINT$ are significant in Stage 1. Furthermore, $SIZE$, $GROUP$, and seller concentration ($COMP$) stimulates innovation, whereas the effect of AGE is negative. However, the likelihood-ratio-test does not reject the hypothesis of independence of stage 1 and 2. Thus, selectivity does

[28] $INNO$ equals one if the firm either had a product or process innovation, or has ongoing or abandoned innovation activities in the period 2004-2006, zero else.

[29] Admittedly, we cannot test the validity of the exclusion restrictions, however, it turns out that $DIVERS$ and $EXINT$ were not significant in any regression of financial constraints (CON or $TYPE$).

not seem to play a role here. Consequently, the results do not change considerably compared to the models presented in section 5.1.

Table VI: Probit models on the likelihood of being constrained *(CON)* (2,468 obs.) with alternative measures for innovative capability

Variable	High Qual. Empl. dF/dx	(Std.Err.)	R&D Empl. dF/dx	(Std.Err.)	Inno. Success dF/dx	(Std.Err.)
$B_H M_L$ (β_1)	0.246^{***}	(0.078)	0.353^{***}	(0.075)	0.345^{***}	(0.052)
$B_H M_M$ (β_2)	0.087^{**}	(0.037)	0.165^{***}	(0.043)	0.185^{***}	(0.037)
$B_H M_H$ (β_3)	0.188^{***}	(0.052)	0.269^{***}	(0.080)	0.217^{***}	(0.047)
$B_L M_L$ (β_4)	0.022	(0.045)	0.032	(0.043)	0.024	(0.051)
$B_L M_M$ (β_5)	-0.028	(0.020)	-0.021	(0.023)	-0.024	(0.022)
Log-likelihood	-1,493.462		-1,474.725		-1,467.402	
McFadden's R^2/Count R^2	0.073/0.658		0.085/0.672		0.090/0.683	
McKelvey & Zavoina's R^2	0.160		0.179		0.181	
AIC / BIC	1.237/-16,033.258		1.222/-16,070.732		1.216/-16,085.378	
Joint sig. ind. dummies	$\chi^2(14) = 641.61^{***}$		$\chi^2(14) = 738.70^{***}$		$\chi^2(14) = 352.40^{***}$	
H_1: $\beta_1 > \beta_4$	$p = 0.008^{***}(^{\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$	
H_1: $\beta_2 > \beta_5$	$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$	
H_1: $\beta_3 > 0$	$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.000^{***}(^{\diamond\diamond\diamond})$		$p = 0.009^{***}(^{\diamond\diamond\diamond})$	
H_2: $\beta_1 > \beta_2$	$p = 0.013^{**}(^{\diamond\diamond})$		$p = 0.017^{**}(^{\diamond})$		$p = 0.004^{***}(^{\diamond\diamond})$	
H_2: $\beta_1 > \beta_3$	$p = 0.176(-)$		$p = 0.141(-)$		$p = 0.010^{**}(^{\diamond\diamond})$	
H_2: $\beta_2 > \beta_3$	$p = 0.982(-)$		$p = 0.943(-)$		$p = 0.775(-)$	
H_3: joint sig. test of $\beta_{15} - \beta_{18}$	$\chi^2(4) = 10.97^{**}$		$\chi^2(4) = 14.78^{***}$		$\chi^2(4) = 9.72^{**}$	

Notes: see Table III. The same specification as in Model 2 of Table II is used. Results for variables not reported here are available upon request.

Table VII: Probit / Ordered Probit model with selection (2,468 obs.)

	Probit Model				Ordered Probit Model					
	Stage 1: INNO		Stage 2: CON		Stage 2: TYPE					
					Outcome 0		Outcome 1		Outcome 2	
Variable	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)	dF/dx	(Std.Err.)
$B_H M_L$ (β_1)			0.263***	(0.052)	-0.263***	(0.052)	0.215***	(0.034)	0.048**	(0.020)
$B_H M_M$ (β_2)			0.085**	(0.036)	-0.100***	(0.031)	0.089***	(0.027)	0.011**	(0.004)
$B_H M_H$ (β_3)			0.114**	(0.058)	-0.143***	(0.051)	0.125***	(0.042)	0.018*	(0.010)
$B_L M_L$ (β_4)			0.042	(0.060)	-0.032	(0.052)	0.028	(0.047)	0.003	(0.006)
$B_L M_M$ (β_5)			-0.022	(0.031)	0.011	(0.024)	-0.010	(0.022)	-0.001	(0.002)
$ln(SIZE)^{\dagger}$	0.048***	(0.007)	0.030**	(0.012)	-0.025***	(0.008)	0.022***	(0.007)	0.002***	(0.001)
$ln(AGE)$	-0.042***	(0.012)	0.011	(0.017)	-0.013	(0.017)	0.012	(0.015)	0.001	(0.002)
$ln(PLC)$	0.005	(0.010)	-0.021	(0.018)	0.020	(0.016)	-0.018	(0.014)	-0.002	(0.002)
$EAST$	-0.028	(0.018)	-0.026	(0.026)	0.043*	(0.024)	-0.039*	(0.022)	-0.004*	(0.002)
FIN_DEP			-0.051***	(0.030)	0.064**	(0.027)	-0.059**	(0.025)	-0.005**	(0.003)
$R\&D\_DEP$			0.048	(0.046)	-0.034	(0.035)	0.031	(0.032)	0.003	(0.004)
$SALES\_DEP$			-0.026	(0.051)	0.025	(0.043)	-0.023	(0.039)	-0.002	(0.004)
$OTHER\_DEP$			-0.004	(0.045)	-0.014	(0.043)	0.013	(0.039)	0.001	(0.004)
$COMP$	0.001***	(0.001)	0.001	(0.001)	-0.001	(0.001)	0.001	(0.001)	0.001	(0.001)
$FAMCOM$ (β_{15})	0.015	(0.027)	0.049**	(0.023)	-0.040*	(0.021)	0.036*	(0.019)	0.004*	(0.002)
$GROUP$ (β_{16})	0.059***	(0.022)	-0.034	(0.036)	-0.006	(0.031)	0.005	(0.028)	0.001	(0.003)
$KAPINT^{\dagger}$ (β_{17})	-0.020	(0.028)	-0.128**	(0.062)	0.141**	(0.055)	-0.128**	(0.050)	-0.013**	(0.006)
$RATING$ (β_{18})			-0.023	(0.020)	0.013	(0.019)	-0.012	(0.017)	-0.001	(0.002)
$EXINT^{\dagger}$	0.003***	(0.001)								
$DIVERS$	0.023*	(0.014)								
Log-likelihood	-2,389.065				-2,490.640					
Rho	0.016				-0.067					
Joint sig. ind. dummies	$\chi^2(28) = 71,401.80^{***}$				$\chi^2(28) = 6.3e+05^{***}$					
H_1: $\beta_1 > \beta_4$	$p = 0.003^{***}(^{\diamond\diamond\diamond})$				$p = 0.000^{***}(^{\diamond\diamond\diamond})$					
H_1: $\beta_2 > \beta_5$	$p = 0.002^{***}(^{\diamond\diamond\diamond})$				$p = 0.000^{***}(^{\diamond\diamond\diamond})$					
H_1: $\beta_3 > 0$	$p = 0.049^{**}(^{-})$				$p = 0.004^{***}(^{\diamond\diamond})$					
H_2: $\beta_1 > \beta_2$	$p = 0.000^{***}(^{\diamond\diamond\diamond})$				$p = 0.003^{***}(^{\diamond\diamond\diamond})$					
H_2: $\beta_1 > \beta_3$	$p = 0.004^{***}(^{\diamond\diamond})$				$p = 0.019^{**}(^{\diamond})$					
H_2: $\beta_2 > \beta_3$	$p = 0.728(^{-})$				$p = 0.853(^{-})$					
H_3: joint sig. test of $\beta_{15} - \beta_{18}$	$\chi^2(4) = 11.21^{**}$				$\chi^2(4) = 10.27^{**}$					

Notes: see Table III. (†): Lagged values (t-1) are used in Stage 1.

Finally, this study made use of a direct indicator of financial constraints. To test whether this indicator really captures what we expect it to do, we conduct an admittedly rough test of the validity of the survey-based constraint indicator (CON). For this purpose, we estimate the sensitivity of firms' *actual* innovation expenditure ($INNOEXP$) to the availability of internal funds and to the access to external funds for both the group of potentially constrained ($CON = 1$) and unconstrained firms ($CON = 0$). For comparability reasons we follow Czarnitzki and Hottenrott (2011a,b) and measure internal liquidity by the empirical price-cost-margin PCM.[30] Access to external funds is proxied by the credit rating index ($RATING$). We distinguish 5 rating classes based on the distribution of $RATING$, each class covering 20 percent of the distribution. We control for firms' size measured by fixed assets ($ASSETS$), age of the firm (AGE), market (seller) concentration (COMP) and industry. To avoid direct simultaneity, we use lagged values for all time-variant explanatory variables.[31]

We expect a higher sensitivity for firms that were categorized as constrained. This is confirmed by the results (see Table VIII). Innovation expenditure increases significantly with an increase in internal liquidity for group $CON = 1$, but not for $CON = 0$. Furthermore, the marginal effects of $RATING_3$ (only for $CON = 1$), $RATING_4$ and $RATING_5$ turn out to be significantly negative. That is, firms with a worse credit rating spend less on innovation than the firms in the top 20th percentile (which serves as the reference group). Comparing marginal effects across groups, $RATING_3$ is significantly larger for the constrained group[32].

[30] The MIP data used for this study does not provide any information on cash flow. PCM = (Sales - Staff Cost - Material Cost + $\delta R\&D$)/Sales.

[31] We estimate Tobit models on the following innovation investment equation

$$ln(INNOEXP) = \beta_0 + \beta_1 ASSETS + \beta_2 ASSETS^2 + \beta_3 AGE + \beta_4 COMP + \beta_5 PCM + \sum_{k=6}^{10} \beta_k RATING_c + \sum_{l=11}^{24} \beta_l IND. \quad (8)$$

[32] The t-statistic equals 1.65. Concerns regarding the potential endogeneity of the credit rating have been discussed in detail in Czarnitzki and Hottenrott (2011a).

Table VIII: Tobit models on innovation expenditures ($INNOEXP$) by CON

	CON=1		CON=0	
Variable	**dF/dx**	**(Std.Err.)**	**dF/dx**	**(Std.Err.)**
PCM	0.968***	(0.342)	0.016	(0.018)
$RATING_2$	-0.154	(0.428)	-0.133	(0.367)
$RATING_3$	-1.264***	(0.451)	-0.600	(0.373)
$RATING_4$	-1.024**	(0.455)	-0.831**	(0.372)
$RATING_5$	-0.787*	(0.455)	-0.900**	(0.375)
$ln(ASSETS)$	0.718***	(0.063)	0.479***	(0.054)
$ln(ASSETS)^2$	0.046***	(0.006)	0.025***	(0.005)
$ln(AGE)$	-0.202	(0.190)	-0.273*	(0.159)
$COMP$	0.004**	(0.002)	0.004**	(0.002)
# obs.	887		1,581	
# censored obs.	96		731	
Log-likelihood	-2,379.577		-3,622.507	
Joint sig. ind. dummies	$F(14, 864) = 8.06$***		$F(14, 1558) = 19.92$***	

***(**,*) indicate a significance level of 1% (5%, 10%). Both models contain a constant and industry dummies. dF/dx denotes the change in the conditional expectation.

6 Conclusions

Financing conditions for innovation activities in imperfect capital markets may be one reason for welfare reducing under-investment in knowledge capital. Firms with limited internal funds may have to leave some of their innovation projects on the shelf due to restricted access to external financing. Such projects would be profitable at the internal rate of return but are not rewarding given the 'risk-premium' on the cost of external capital.

This article contributes to the literature on financing constraints for innovation in three main aspects. First, a new approach of measuring financial constraints allows us to estimate the likelihood of being constrained as well as the degree based on a direct indicator derived from a test closer to the 'ideal test' as suggested by Hall (2008). By using multivariate probit models, we secondly take into account that the decision to engage in innovation projects is part of the firms' overall optimization process. Third, we derive a framework that attributes financing constraints not only to the lack of financial resources but also to the firms' innovative capability.

Our econometric analysis supports the hypothesis that financial constraints hold back innovation activities. We find firms with higher innovative capability to be more likely to have unexploited innovation projects, independent of their financial background (Hypothesis 1). Our results further show that firms with high innovative capability and low levels of internal funds are more likely to be constrained than their more liquid counterparts (Hypothesis 2). In summary, firms with high innovative capability but low financial resources turn out most likely to be constrained.

Is this result surprising as innovation capabilities are necessary to do innovation? It could be argued that firms with high capabilities are able to attract funds easier because of the higher expected success of their projects. This study, however, suggests the opposite. Investors - although they might be aware of the fact that skills are an important success factor of R&D - do not sufficiently value such skills. Uncertainty about the outcome of innovation projects seems to outweigh information on skills. Firms investing in intangible assets such as human capital instead of physical capital may even experience an additional disadvantage in raising funds due to lower 'relative collateral value'. Hence, financial constraints do not depend on the availability of internal funds per se, but are driven by innovative capability.

We further find that low capital intensity has a significant effect on the likelihood and degree of being constrained (Hypothesis 3). On the other hand, our main variables of interest play a fundamentally different role in the decision to invest in physical capital. Here, a low innovative capability leads to a higher likelihood of choosing additional capital investments. The multidimensional analysis further reveals that in contrast to the innovation choice, the decision to serve debt is to a large extent driven by the financial background. Consequently, firms with low internal funds or bad credit ratings would primarily repay debt instead of investing additional cash in new innovation projects.

Another notable result of our study is 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. In particular, we expect that family-run businesses would answer differently if loans at a comparatively low interest rate would have been offered instead of cash. Future research will be directed to how much the results depend on the fact that the question offers cash only.

From a policy point of view, we conclude that a significant portion of firms is financially constrained, particularly firms with high innovative capability. Hence, policy should stimulate the provision of risk-taking external capital and provide public funding. If innovative capability is the driving force behind financing constraints, this should be regarded as an important criterion for supporting private investment in innovation. Either project selection or granting tax credits could account for such factors as they reflect the firms' ability to release unexploited innovation potential and turn ideas into innovative products or processes.

7 Appendix

Table A.1: Industries and *CON* by industries (2,468 obs.)

Industry	Freq.	%	Mean prob. CON	Mean prob. TYPE		
				TYPE(0)	TYPE(1)	TYPE(2)
mining	78	3.16	15.38	84.62	15.38	0.00
food/tobacco	172	6.97	28.49	71.51	27.33	1.16
textiles	113	4.58	33.63	66.37	32.74	0.88
paper/wood/print	250	10.13	28.40	71.60	27.60	0.80
chemical	162	6.56	43.21	56.79	38.89	4.32
plastics/rubber	143	5.97	36.36	63.64	34.27	2.10
glas/ceramics	118	4.78	39.83	60.17	39.83	0.00
metal	312	12.64	36.86	63.14	36.22	0.64
machinery	265	10.74	42.64	57.36	39.25	3.40
electr. eng.	186	7.54	50.54	49.46	46.77	3.76
medicine/optic	193	8.82	52.33	47.67	48.70	3.63
vehicles	100	4.05	46.00	54.00	44.00	2.00
furniture	121	4.90	33.89	66.12	32.23	1.65
energy/water	142	4.75	14.79	85.21	14.08	0.70
construction	113	4.58	15.04	84.96	15.04	0.00
Total	2,468	100.00	35.90	64.06	34.12	1.82

Table A.2: Profit-margin categories (2,468 obs.)

	Profit-margin	**Frequency**	**%**	**Cum.**	**Category**
1	<0%	272	11.02	11.02	M_L
2	0% - <2%	419	16.98	28.00	M_M
3	2% - <4%	467	18.92	46.92	M_M
4	4% - <7%	604	24.47	71.39	M_M
5	7% - <10%	348	14.10	85.49	M_H
6	10% - <15%	209	8.47	93.96	M_H
7	>=15%	149	6.04	100.00	M_H
	Total	2,468	100.00		

Table A.3: Correlation coefficients between equations in MV-probit (2,468 obs.)

	equ_1	equ_2	equ_3	equ_4
equ_2	0.564 (0.029)			
equ_3	-0.167 (0.033)	-0.110 (0.034)		
equ_4	-0.312 (0.036)	-0.245 (0.038)	0.116 (0.037)	
equ_5	-0.232 (0.033)	-0.101 (0.034)	0.018 (0.033)	0.029 (0.038)

Table A.4: Sensitivity analysis

IC	Cut-off	% B_H	H_1 confirmed?	H_2 confirmed?	H_3 confirmed?
Benchmark					
High.qual. empl. & train.	at 80%	33%	yes	partly ($\beta_1 > \beta_2$, $\beta_1 > \beta_3$, but $\beta_2 = \beta_3$)	yes
High.qual. empl. & train.	at mean	44%	yes	partly ($\beta_1 > \beta_2$, but $\beta_1 = \beta_3$, $\beta_2 = \beta_3$)	yes
High.qual. empl. & train.	at median	66%	yes	partly ($\beta_1 > \beta_2$, but $\beta_1 = \beta_3$, $\beta_2 = \beta_3$)	yes
High.qual. empl. & train.	at 90%	19%	partly ($\beta_2 = \beta_5$, $\beta_3 > 0$, but$\beta_1 = \beta_4$)	partly ($\beta_1 > \beta_2$, but $\beta_1 = \beta_3$, $\beta_2 = \beta_3$)	yes
High.qual. empl. & train.	at 80%+	32%	yes	partly ($\beta_1 > \beta_2$, $\beta_1 > \beta_3$, but $\beta_2 = \beta_3$)	yes
High.qual. empl. only	at 80%	20%	yes	partly ($\beta_1 > \beta_2$, but $\beta_1 = \beta_3$, $\beta_2 = \beta_3$)	yes
R&D empl.	at 80%	20%	yes	partly ($\beta_1 > \beta_2$, $\beta_1 > \beta_3$, but $\beta_2 = \beta_3$)	yes
Past inno. success	at median	26%	yes	partly ($\beta_1 > \beta_2$, $\beta_1 > \beta_3$, but $\beta_2 = \beta_3$)	yes

+relative to industry

Table A.5: Cross-correlation table

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	CON	1.000																				
2	TYPE	0.968	1.000																			
3	M_L	0.028	0.026	1.000																		
4	M_M	-0.042	-0.046	-0.434	1.000																	
5	M_H	0.027	0.032	-0.223	-0.781	1.000																
6	B_L	-0.133	-0.153	-0.018	0.087	-0.082	1.000															
7	B_H	0.133	0.153	0.018	-0.087	0.082	-1.000	1.000														
8	ln(SIZE)	0.137	0.122	-0.055	0.045	-0.010	-0.147	1.000	1.000													
9	ln(AGE)	0.004	0.008	-0.061	0.047	-0.009	0.004	0.008	0.137	1.000												
10	FAMCOM	0.033	0.026	-0.058	0.104	-0.072	0.105	-0.105	-0.113	0.007	1.000											
11	PLC	-0.089	-0.091	-0.004	-0.015	0.018	0.037	-0.037	-0.045	0.052	-0.082	1.000										
12	EAST	-0.048	-0.054	0.021	0.031	-0.048	-0.103	0.103	-0.155	-0.233	-0.130	-0.018	1.000									
13	GROUP	0.059	0.068	0.022	-0.042	0.030	-0.016	0.016	0.503	0.089	-0.218	0.003	-0.096	1.000								
14	COMP	0.060	0.064	-0.015	-0.039	0.053	-0.143	0.143	0.106	-0.012	-0.150	-0.015	0.019	0.092	1.000							
15	KAPINT	-0.085	-0.085	-0.002	-0.049	0.054	0.007	-0.007	0.008	0.038	-0.183	0.178	0.045	0.077	0.084	1.000						
16	RATING	-0.049	-0.040	0.108	0.028	-0.105	-0.056	0.056	-0.312	-0.127	0.010	-0.035	0.118	-0.178	-0.045	-0.086	1.000					
17	$ln(CASH)_{c1}$	-0.105	-0.101	0.104	-0.094	0.030	-0.121	0.121	-0.585	-0.126	0.053	0.010	0.108	-0.276	-0.068	-0.063	0.212	1.000				
18	$ln(CASH)_{c2}$	-0.027	-0.033	-0.037	0.054	-0.033	-0.037	0.037	-0.305	-0.054	0.040	-0.014	0.071	-0.223	-0.035	-0.024	0.160	-0.249	1.000			
19	$ln(CASH)_{c3}$	-0.032	-0.026	-0.015	0.034	-0.027	0.072	-0.072	-0.034	0.009	0.068	-0.012	0.050	-0.125	-0.038	-0.006	0.003	-0.249	-0.251	1.000		
20	$ln(CASH)_{c4}$	0.074	0.072	-0.001	0.042	-0.045	0.070	-0.070	0.230	0.057	0.030	0.010	-0.036	0.127	0.041	0.042	-0.114	-0.248	-0.250	-0.251	1.000	
21	$ln(CASH)_{c5}$	0.091	0.088	-0.050	-0.037	0.075	0.015	-0.015	0.691	0.113	-0.190	0.006	-0.193	0.495	0.099	0.051	-0.260	-0.249	-0.251	-0.251	-0.250	1.000

References

Aghion, P., P. Askenazy, N. Berman, G. Cette, and L. Eymard, "Credit Constraint and the Cyclicality of R&D Investment: Evidence from France", Paris School of Economics Working Paper 2008 - 26 (2008).

Akerlof, G. A., "The Market for 'Lemons': Quality, Uncertainty, and the Market Mechanism", *Quarterly Journal of Economics* 84 (1970), 488–500.

Alderson, M. and B. Betker, "Liquidation Costs and Accounting Data", *Financial Management* 25:2 (1996), 25–36.

Anton, J. and D. Yao, "The Sale of Ideas: Strategic Disclosure, Property Rights, and Contracting", *Review of Economic Studies* 69:3 (2002), 513–531.

Arrow, K., "Economic Welfare and the Allocation of Resources for Invention", in: Nelson, R. R. (ed.), *The Rate and Direction of Inventive Activity, Economic and Social Factors*, Princeton: Princeton University Press (1962), 609–625.

Auerbach, A., "Wealth Maximization and the Cost of Capital", *The Quarterly Journal of Economics* 93:3 (1979), 433–446.

Aydogan, A., "How Sensitive Is Investment to Cash Flow When Financing Is Frictionless?", *The Journal of Finance* 58:2 (2003), 707–722.

Bhattacharya, S. and J. Ritter, "Innovation and Communication: Signalling with Partial Disclosure", *Review of Economic Studies* 50:2 (1983), 331–346.

Bond, S. and J. Van Reenen, "Microeconometric Models of Investment and Employment", in: Heckman, J. and E. Leamer (eds.), *Handbook of Econometrics*, Vol. 6 (2007), 4417–4498.

Bougheas, S., H. Görg, and E. Strobl, "Is R&D Financially Constrained? Theory and Evidence from Irish Manufacturing", *Review of Industrial Organization* 22:2 (2003), 159–174.

Brown, J., S. Fazzari, and B. Petersen, "Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom", *Journal of Finance* 64:1 (2009), 151–185.

Brown, J. and B. Petersen, "Why has the Investment-Cash Flow Sensitivity Declined so Sharply? Rising R&D and Equity Market Developments", *Journal of Banking and Finance* 33 (2009), 971–984.

Canepa, A. and P. Stoneman, "Financial Constraints on Innovation: A European Cross-Country Study", EIFC - Technology and Finance Working Papers 011, Warwick (2002).

Carpenter, R. and B. Petersen, "Capital Market Imperfections, High-Tech Investment, and New Equity Financing", *The Economic Journal* 112 (2002), 54–72.

Cleary, S., "The Relationship between Firm Investment and Financial Status", *Journal of Finance* 54:2 (1999), 673–692.

Czarnitzki, D., "Research and Development in Small- and Medium-Sized Enterprises: The Role of Financial Constraints and Public Funding", *Scottish Journal of Political Economy* 53:3 (2006), 257–335.

Czarnitzki, D. and H. Hottenrott, "Financial Constraints: Routine Versus Cutting Edge R&D Investment", *Journal of Economics and Management Strategy* 20:1 (2011a), 121–157.

Czarnitzki, D. and H. Hottenrott, "R&D Investment and Financing Constraints of Small and Medium-Sized Firms", *Small Business Economics,* forthcoming (2011b).

David, P., B. Hall, and A. Toole, "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence", *Research Policy* 29 (2000), 497–529.

Dhanani, A., "Corporate Dividend Policy: The Views of British Financial Managers", *Journal of Business Finance & Accounting* 32:7&8 (2005), 1625–1672.

Easterbrook, F., "Two Agency-Cost Explanations of Dividends", *The American Economic Review* 74:4 (1984), 650–659.

Fazzari, S., R. Hubbard, and B. Petersen, "Financing Constraints and Corporate Investment", *Brookings Papers on Economic Activity* 1 (1988), 141–206.

Fazzari, S., R. Hubbard, and B. Petersen, "Investment-Cash Flow Sensitivities are Useful: A Comment on Kaplan and Zingales", *The Quarterly Journal of Economics* 115:2 (2000), 695–705.

Geweke, J., "Bayesian Inference in Econometric Models Using Monte Carlo Integration", *Econometrica* 57 (1989), 1317–1339.

Grabowski, H. and D. Mueller, "Managerial and Stockholder Welfare Models of Firm Expenditures", *Review of Economics and Statistics* 54 (1972), 9–24.

Greenwald, B., J. Stiglitz, and A. Weiss, "Information Imperfections and Macroeconomic Fluctuations", *American Economic Review* 74 (1984), 194–199.

Guerard, J., A. Bean, and S. Andrews, "R&D Management and Corporate Financial Policy", *Management Science* 33:11 (1987), 1419–1427.

Gugler, K., "Corporate Governance, Dividend Payout Policy, and the Interrelation Between Dividends, R&D, and Capital Investment", *Journal of Banking and Finance* 27 (2003), 1297–1321.

Hajivassiliou, V. and D. McFadden, "The Method of Simulated Scores for the Estimation of LDV Models", *Econometrica* 66 (1998), 863–896.

Hajivassiliou, V. and P. Ruud, *Handbook of Econometrics*, Vol. 4, Chap. Classical Estimation Methods for LDV Models Using Simulation (1994), Amsterdam: North-Holland, 2383–2441.

Hajivassiliou, V. and F. Savignac, "Financing Constraints and a Firm's Decision and Ability to Innovate: Establishing Direct and Reverse Effects", Banque de France, Notes d'Études et de Recherche NER - R # 202 (2008).

Hall, B., "The Impact of Corporate Restructuring on Industrial Research and Development", *Brooking Papers on Economic Activity* 1 (1990), 85–136.

Hall, B., "Investment and Research and Development at the Firm Level: Does the Source of Financing Matter?", NBER Working Paper 4096, Cambridge, MA. (1992).

Hall, B., "Firm-Level Investment with Liquidity Constraints: What Can the Euler Equation Tell Us?", Mimeo, Cambridge, MA. (1995).

Hall, B., "The Financing of Research and Development", *Oxford Review of Economic Policy* 18:1 (2002), 35–51.

Hall, B., "The Financing of Innovation, in: Handbook of Technology and Innovation Management", in: Shane, S. (ed.), *Handbook of Technology and Innovation Management*, Blackwell Publishers: Oxford (2008), 409–430.

Hall, B., Z. Griliches, and J. Hausman, "Patents and R&D: Is There a Lag?", *International Economic Review* 27 (1986), 265–283.

Harhoff, D., "Are There Financing Constraints for R&D and Investment in German Manufacturing Firms?", *Annales d' Economie et de Statistique* 49/50 (1998), 421–456.

Himmelberg, C. and B. Peterson, "R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries", *Review of Economics and Statistics* 76 (1994), 38–51.

Howe, J. and D. McFetridge, "The Determinants of R&D Expenditures", *The Canadian Journal of Economics* 9:1 (1976), 57–71.

Hubbard, R., "Capital-Market Imperfections and Investment", *Journal of Economic Literature* 36:1 (1998), 193–225.

Jensen, M., "Agency Cost of Free Cash Flow, Corporate Finance, and Takeovers", *American Economic Review* 76 (1986), 323–339.

Jensen, M. and W. Meckling, "The Theory of the Firm: Managerial Behavior, Agency Cost, and Ownership Structure", *Journal of Financial Economics* 3 (1976), 305–360.

Kaplan, S. and L. Zingales, "Do Investment-Cash Flow Sensitivities Provide Useful Measures of Financing Constraints?", *The Quarterly Journal of Economics* 112:1 (1997), 169–215.

Kaplan, S. and L. Zingales, "Investment-Cash Flow Sensitivities Are Not Valid Measures of Financing Constraints", *The Quarterly Journal of Economics* 115:2 (2000), 707–712.

Keane, M., "A computational practical simulation estimator for panel data", *Econometrica* 62 (1994), 95–116.

Lach, S. and M. Schankerman, "Dynamics of R&D and Investment in the Scientific Sector", *Journal of Political Economy* 97:4 (1988), 880–904.

Leland, H. and D. Pyle, "Informational Asymmetries, Financial Structure, and Financial Intermediation", *Journal of Finance* 32 (1977), 371–387.

Martinsson, G., "Equity Financing and Innovation: Is Europe Different from the United States?", *Journal of Banking and Finance* 34:6 (2010), 1215–1224.

Meyer, J. R. and E. Kuh, *The Investment Decision: An Empirical Study* (Cambridge, MA: Harvard University Press, 1957).

Modigliani, F. and M. Miller, "The Cost of Capital, Corporation Finance and the Theory of Investment", *American Economic Review* 48 (1958), 261–297.

Nelson, R., "The Simple Economics of Basic Scientific Research", *Journal of Political Economy* 49 (1959), 297–306.

Peters, B., *Innovation and Firm Performance: An Empirical Investigation for German Firms*, ZEW Economic Studies, *Innovation and Firm Performance: An Empirical Investigation for German Firms* (Heidelberg, New York: Physica, 2008).

Peters, B. and P. Westerheide, "Short-term Borrowing for Long-term Projects: Are Family Businesses More Susceptible to Irrational Financing Choices?", ZEW Discussion Paper 11-006, Mannheim (2011).

Piga, C. and G. Atzeni, "R&D Investment, Credit Rationing and Sample Selection", *Bulletin of Economic Research* 59:2 (2007), 149–178.

Roodman, D., "Estimating Fully Observed Recursive Mixed-Process Modles with cmp", Center for Global Development, CGD Working Paper 168, Washington D.C. (2009).

Savignac, F., "Impact of Financial Constraints on Innovation: What Can Be Learned from a Direct Measure?", *Economics of Innovation and New Technology* 17:6 (2008), 553–569.

Schiantarelli, F., "Financial Constraints and Investment: Methodological Issues and International Evidence", *Oxford Review of Economic Policy* 12 (1996), 70–89.

Stiglitz, J., "Credit Markets and the Control of Capital", *Journal of Money, Credit and Banking* 17 (1985), 393–410.

Stiglitz, J. and A. Weiss, "Credit Rationing in Markets with Imperfect Information", *American Economic Review* 71 (1981), 393–410.

Tiwari, A., P. Mohnen, F. Palm, and S. Schim van der Loeff, "Financial Constraint and R&D Investment: Evidence from CIS", UNU-MERIT Working Paper Series 011, Maastricht (2007).

Train, K., *Discrete Choice Methods with Simulation* (Cambridge: Cambridge University Press, 2009).

Verbeek, M., *A Guide to Modern Econometrics* (West Sussex: Wiley, 2000).

Williamson, O., "Corporate Finance and Corporate Governance", *Journal of Finance* 43:3 (1988), 567–591.