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DISCUSSION PAPER

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Financial Constraints for R&D and Innovation: New Evidence From a Survey Experiment

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Financial Constraints for R&D and Innovation: New Evidence from a Survey Experiment*

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Abstract

We utilize a new survey experiment to evaluate the existence and degree of financial constraints for R&D in the economy. The experiment does not only allow to deduct the presence of financial constraints, but also to evaluate their economic significance. Using data on German companies, we find that financial constraints for R&D exist but that their relevance might have been overestimated in the literature. Most R&D projects that have not been implemented because of financial constraints turn out to have low expected marginal rates of return. While this findings stands in some contrast to other studies, we also find several results that are in line with the literature: young firms are most constrained and the constraints occur at the intensive margin, i.e. our results do not suggest that non-innovative companies are deterred from innovation. Instead, highly innovative companies are restricted by the capital market.

Keywords: Innovation, Financial Constraints, Survey Experiment

JEL-Classification: G30, O30, O31, O32, L21

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1 Introduction

The debates about financial constraints for innovation have a long tradition in the field of economics. Early considerations started with Arrow (1962) who outlined the asymmetric information problem between buyers and lenders because of the complexity, specificity and high uncertainty of outcome of research and development (R&D) projects. These factors make it difficult for potential lenders to judge about the expected returns of the investment. In addition, R&D has a low inside collateral value, because the lion's share of R&D are wages and thus expenses which are immediately sunk. Thus, R&D and innovation project are, if at all possible, more costly to be financed by external capital. Therefore, firms might have to rely on internal resources. Since these are not unlimited, financial constraints for innovation occur.

Identifying financial constraints for innovation turned out to be challenging in empirical research. Building on Fazzari et al. (1988), works identified financing constraints for R&D by differences in sensitivity to cash-flow between different types of firms (e.g., Brown et al. 2009; Himmelberg and Petersen 1994). This approach has, however, been highly criticized by Kaplan and Zingales (1997, 2000) who doubted that investment-cash-flow sensitivities can be interpreted as financial constraints. Building on this debate, a large literature emerged where scholars tried to utilize different concepts to identify financial constraints (e.g., Farre-Mensa and Ljungqvist, 2016; Hall 2002, Hall 2008, Hall and Lerner 2010) and their impact on innovation (see e.g., Czarnitzki and Hottenrott 2010; He and Tian 2018; Kerr and Nanda 2015).

We contribute to this discussion about the impact of financing constraints on innovation by building on a thought experiment outlined by Hall (2008). Hall suggested that "the ideal experiment for identifying the effects of liquidity constraints on investment is to give firms additional cash flow 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." (Hall and Lerner 2010, 619). Conducting this experiment in reality would lead to valuable information concerning the existence of financing constraints of firms in the first place. At second glance, however, it becomes clear, that further information is needed to determine which type of not executed innovation projects are facilitated with the additional investments.

To test for financing constraints and the characteristics of related, not executed innovation projects, we exploit information from a comparable hypothetical experiment that was included in the German part of the Community Innovation Survey. This enables us to extend the initial idea of Hall (2008), by utilizing a survey experiment, which also asked a large sample of firms how they would invest if they could get additional resources by taking out a cheap loan. This allows conclusions about the expected private returns to R&D and innovation in Germany by comparing the investment plans for free cash-flow and low cost loans.

Our survey experiment reveals a number of new findings and confirms some expected results that have been found in earlier literature. First, we show that the extent of severe financial constraints might be much lower than one could expect from the literature. Second, we find that especially young firms and innovation-intensive firms are financially constrained. Third, by considering further survey information, we show that especially innovation projects with high social returns might not be implemented because of severe financial constraints. Furthermore, we find that about 2/3 of firms indicating that they are financially constrained in their innovation activity do not have non-executed projects with a high expected private economic returns in their portfolio.

Our paper contributes to several strands of literature. In the area of R&D and innovation, scholars have used credit ratings (Fazzari et al. 2000; Czarnitzki and Hottenrott 2011a; Czarnitzki and Hottenrott 2011b), loan requests and defaults (Piga and Atzeni 2007; Aghion et al. 2012), government subsidies (Hyytinen and Toivanen 2005; Czarnitzki, 2006), exogenous shocks such as the financial crisis affecting firms directly or indirectly through shocks in the

bank lending market (Giebel and Kraft 2019a; 2019b; 2020, Spatareanu et al. 2019) as well as survey data on hampering factors (Savignac, 2008) to identify financing constraints.

We add to these works by investigating financing constraints for innovation by exploiting and extending the survey experiment proposed by Hall (2008). This also supplements the influential work by Hottenrott and Peters (2012) who also build on the experimental idea proposed by Hall (2008). Their work shows that financing constraints rather depend on innovation capability of firms than the availability of internal funds. By extending the survey experiment, we identify more binding constraints than Hottenrott and Peters (2012). We also shed more light on the type of innovation projects the firms would pursue with additional financing. The original work of Hottenrott and Peters (2012) was built on the hypothetical question of how a firm would invest unanticipated windfall profits. In our data, it was also inquired whether firms would take up a cheap loan for investment projects. Our identification strategy relies on the implied shift in marginal costs from zero with windfall profits to positive interest rates of loans and the associated rates of return of the non-implemented projects. By differentiating projects by their expected rates of return, we thus implicitly propose a new identification strategy of financial constraints that are binding such that they impede the implementation of projects that have expected rates of return that are larger than market interest rates. In the second part of the empirical analysis, we also offer some descriptive evidence on the characteristics of forgone innovation projects due to financial constraints and suggest that these projects have societal value as they would, in expectation, contribute to technological progress and would create new markets, for example.

The remainder of the paper is as follows: the second section outlines the conceptual background of our survey experiment, i.e. the identification of financial constraints. Section 3 describes the data. The empirical results are presented in Sections 4 and 5. Section 6 concludes.

2 Conceptual Background

We mainly build on Howe and McFetridge (1976), David et al. (2000), Hall (2008) and Hottenrott and Peters (2012) who have used stylized demand and supply models for R&D and internal as well as external finance. Suppose a firm has a certain number of ideas for research, development and innovation (RDI) projects. The quality of the ideas depends on the innovative capability of the firm (*IC*). The firm ranks the projects according to their expected rate of return, and one thus obtains a downward-sloping demand function reflecting the marginal rate of return (*MRR*). The MRR function *f* may also depend on the level of *RDI* expenditure and other firm and industry characteristics (*X*):

$$MRR = f(IC, RDI, X).$$

A profit-maximizing firm will invest into *RDI* until the MRR equals the marginal cost of capital (*MCC*). The *MCC* function g will vary with the opportunity cost of innovation investments, such as investments in other assets (*K*) and the level of the investment (*RDI*) in combination with the firm's amount of internal funds (*IF*), and the access to external funds. In imperfect capital markets, the external funds have a higher marginal cost of capital than the internal funds. Especially in the context of *RDI*, lenders require a risk premium and therefore, the *MCC* also depend on a firms creditworthiness (*W*). This reflects, among other factors, capital structure and available collateral. The *MCC* function g is determined as

$$MCC = g(IF, K, RDI, W).$$

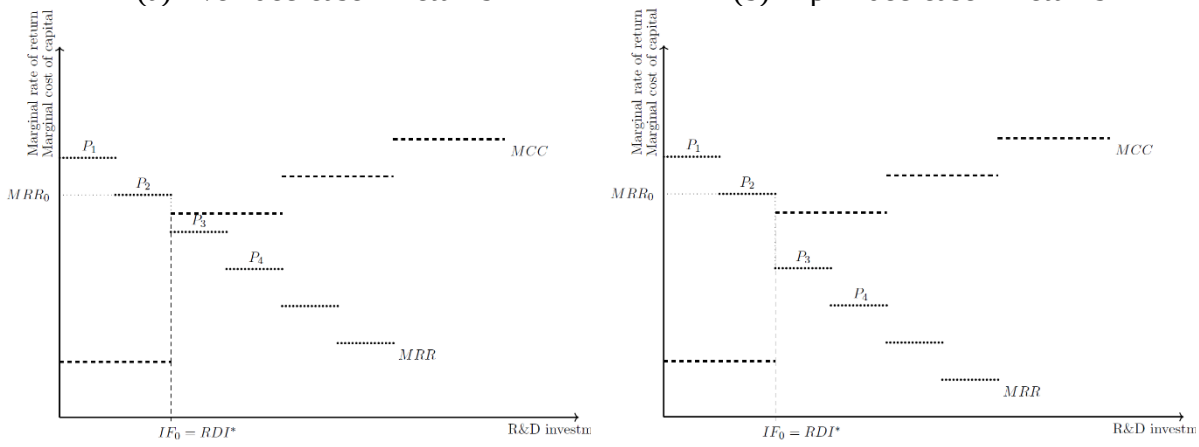
Figure 1 summarizes the implications of the contextualization from above graphically. In the left panel (a), we show a firm that has six project ideas of equal size that are sorted according the *MRR* on the vertical axis. The *MRR* is in this case is evenly decreasing with each additional project. The *MCC* is upward sloping and the firm has internal funds until the point IF_0 on the horizontal axis. Beyond IF_0, the firm would have to seek external financial resources, which

results in higher marginal cost (MC) for additional projects. Consequently, in the left panel (a) of Figure 1, the firm would in equilibrium only use internal funds to finance the *RDI* projects 1 and 2. As the MC for the third project financed by external resources would exceed the *MRR*, this project would not be implemented.

In the right panel (b) of , the *MCC* graph is similar to Figure 1 (a). The *MRR* is almost the same with the exception that the firm experiences a dip in the MRR after the second project. Consequently, it is not anymore evenly or proportionally decreasing with each additional project so that the firm has a more heterogeneous portfolio of innovation projects. While the first two projects have a relatively high marginal rate of return, the following projects have a comparable much lower marginal rate of return. In equilibrium, however, this firm would also implement the first two RDI projects.

Figure 1: Marginal rate of return and marginal cost curve of RDI investments

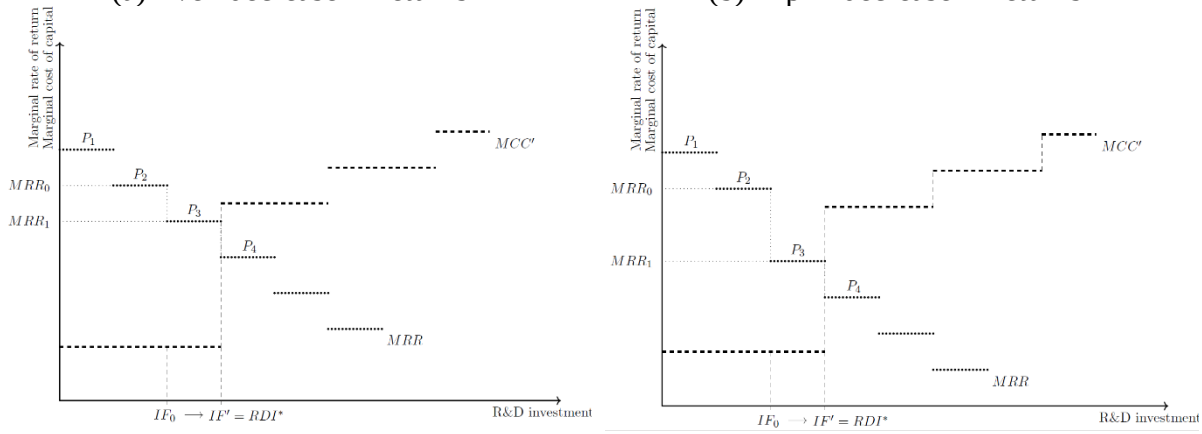
(a) Even decrease in returns (b) Dip in decrease in returns



In the second figure, we pretend that the firm experiences a cash infusion. This leads to a right shift of the *MCC* such that the availability of internal funds moves from IF_0 to *IF'*. Despite differences in the *MRR*, both types of firms depicted in the left and right panel, respectively, would now implement their third most promising project and would finance it by the additional internal funds.

Figure 2: Project implementation with additional internal funds

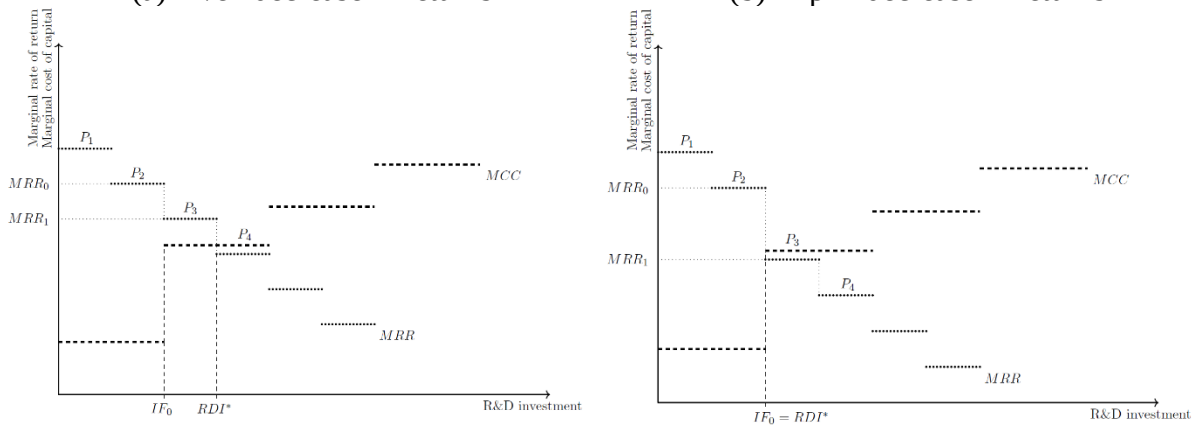
(a) Even decrease in returns (b) Dip in decrease in returns



Instead of a cash infusion, we suppose in Figure 3, that a shock in the lending market reduces the *MCC* for both firms homogenously. Starting again from the equilibrium from Figure 1, the firm in the left panel (a) of Figure 3 would now also implement the three projects with the highest expected returns in its portfolio instead of just the first two as shown in Figure 1. The firm in the left panel would now also obtain a (cheap) loan in order to invest more into *RDI*. The firm in the right panel (b) of Figure 3, however, suffers from a dip in its innovative capability and therefore lower marginal returns from *RDI*. Even with the reduction of the *MCC*, it would not implement the third project as its *MRR* are still not above the now lowered *MCC*.

Figure 3: Shock in lending market reduces MCC

(a) Even decrease in returns (b) Dip in decrease in returns



Our survey experiment has been set up such that we can identify the scenarios presented in the three figures. We asked the firms both whether they would invest in RDI if they would

receive 10% of their returns as windfall profits and also if they would have access to a cheap loan of the same size. This allows conclusions about the private returns of RDI projects that are not implemented in the business sector. In addition, we also show some indication about possible social returns of such projects in the empirical section. If social returns are forgone due to capital market imperfections, a policy intervention seems justified.

3 Data and variables

We use data from the Mannheim Innovation Panel, the German part of the Community Innovation Survey. The data collection follows the harmonized European guidelines as defined in the Oslo-Manual (Eurostat and OECD, 2005).[1] In the survey of the year 2014, relevant questions on hypothetical investment plans have been included. The survey is targeted at manufacturing firms and business-related services with five or more employees. The surveys is a stratified sample and the results can be weighted to estimate population figures.

3.1 Survey experiment

After deleting observations of firm survey responses with missing values in the variables of interest, we end up with a final sample of 3,630 survey responses for this study. Our main variables of interest are the responses to following survey questions: "Suppose your firm would unexpectedly have additional windfall profits or additional equity of 10% of your last annual sales available. How would your firm use these funds? (multiple choices possible)

a. Investment into (additional) assets (without innovative attributes)
b. Implementation of (further) innovation projects
c. Retention of profits / increasing reserves
d. Profit / dividend distribution
e. Debt repayments"

[1] A detailed description of the survey and its methodology can be found in Behrens et al. (2017).

Furthermore, the firms were asked “Suppose now your firm would unexpectedly be offered a loan with a volume of 10% of your last annual sales. Would your firm use that loan for investment into (additional) assets or innovation projects? (Multiple choices possible)

a. Yes, for (additional) investment
b. Yes, for (additional) innovation projects
c. No.”

We use these variables to identify financially constrained firms. By looking at the difference between firms that would use windfall profits versus a cheap loan, we infer how many firms seem only to be mildly constrained and how many are ‘severely’ constrained as they would even use a loan to innovate more. The latter group is constructed as including only firms, which would use both windfall profits and a loan to innovate.

3.2 Implications of financial constraints

In a further step, we identify the characteristics of the unrealized projects, which could be carried out with the additional money available to the firm. For this purpose, we exploit information on the type of projects that have not been implemented, to the extent that is possible with survey data. The firms were asked “Did your enterprise refrain from conducting (certain) innovation activities because of a lack of financial sources?”. If they answered in the affirmative, a follow-up question was asked about the characteristics of the unrealized innovation activities: “To what extent did applies applies apply the following characteristics apply to these not realized innovation activities?

a. High technological intent / degree of novelty
b. High uncertainty over feasibility / market acceptance
c. High marketability / closeness to client requests
d. Entering new market segments / thematic areas”

Answers were possible on a three-point Likert scale ranging from “Fully applies” over “Partly applies” to “Does not apply”.

3.3 Control variables

We consider a number of control variables that allow a judgement about stylized facts on financial constraints as reported in existing literature. The first obvious control variable is firm size. We experimented with non-linear specifications in the regression analysis, and found that size effects are best depicted by just including a dummy variable, 'Small firm', for firms with less than 50 employees, respectively. All larger firms are in the reference category. Similarly, we included the age of the firm, and found it most appropriate to include a dummy variable 'Young firm' for firms up to 6 years after foundation. Furthermore, we include a full set of sector dummies.[2] These variables allow conclusions about the stylized facts that small or young firms in high-tech sectors are supposedly the most financially constrained firms.

In addition, we control for the creditworthiness of the company by including a credit rating obtained from the largest German credit rating agency, Creditreform. The variable `Credit rating' is an index measured between 1 and 6, where 6 is the worst rating and basically reflects bankruptcy (an index from 1 to 6 is stemming from the German grading system). We expect that firms with a bad credit rating have a higher demand for additional resources and would thus be more likely to use windfall profits or newly available loans for innovation projects. Note that we do not include a variable measuring collateral as the experimental survey question on access to loans implies its availability already.

The innovation capability and investment level is reflected by a number of variables: we include the variable 'Innovation intensity', i.e. the firm's innovation expenditure divided by sales, to control for the realized level of investment (relative to the firm size). In addition, innovation capabilities are taken into account by three dummies indicating (i) whether the firm conducts R&D on a permanent basis ('Continuous R&D activity'), (ii) whether the firm has introduced a new product to the market during the recent three years (`Prior product

[2] See Table A1 in Appendix A for an overview of industry dummy variables and the respective share of firms in each industry.

innovation'), (iii) whether a new process has been implemented in the firm's production in the last three years ('Prior process innovation').

Finally, we include some other controls: a dummy 'Part of firm group' indicates whether the firm is part of a consortium. Subsidiaries of large parent companies might have access to resources that make them less prone to financial constraints. In addition, we include an 'Export active' dummy referring to firms that are active on international markets. Finally, we include a variable 'Share of sales with main product' which refers to the share of sales that a company obtains with its most important product or product line in total sales. Less diversified companies may not experience the need to innovate frequently. This could either result from a dominant market position, or because the nature of the product or service do not require frequent improvements or adaptations. In addition to these variables, we also control for the location of the firm. For this purpose, we include a set of federal state dummies.[3]

4 Results for financing constraints

4.1 Descriptive statistics and multiple regression analysis

In this section, we explore which type of firm is most constrained. Therefore, we proceed in two steps. First, we inspect the descriptive statistics of our sample. Second, we run Probit regressions on the probability that firms would have used windfall profits for innovation on the one hand, and a cheap loan on the other hand.

The descriptive statistics of our sample are shown in Table 1. On average, the firms in the sample employ 148 people and are 31 years old. Our experimentations with functional forms in the subsequent regression analysis showed that it is to be preferred to use two dummy variables: one for small firms with less than 50 employees and one for young firms that are not older than six years. The rating value for the average firm is 2.3, which corresponds to the

[3] See Table A2 in Appendix A for an overview of the included federals states and the share of firms included in each category.

category ‘good’. Moreover, about half of the firms are export active and a share of 27 percent is part of a firm group. Concerning the past innovation activities, the numbers in Table 1 indicate that 30 percent of the firms introduced a product innovation and about 22 percent a process innovation.

Next, we compare firms that report that they are not constrained (column 3) and firms, which would take additional cash (column 5). It becomes evident, that constrained firms are larger, younger, more likely exporter and have a higher innovation capability. Comparing the unconstrained firms to firms, which would take additional internal and external financing (column 7), shows the following: The severely constraint firms are smaller, younger, have a weaker rating and have a higher innovation capability. Thus our results support the notion that small and young firms are more likely financially constraint.

Table 1: Descriptive statistics of control variables used in the regression analysis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All firms		No constraints		Constraints			
					Only internal		Internal & external	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Employees	148.49	726.69	135.70	654.98	200.61	1014.83	124.43	305.41
Small firm (less than 50 empl.)	0.642	0.479	0.665	0.472	0.576	0.495	0.616	0.487
Firm age	31.32	33.80	32.08	34.65	29.86	30.80	28.77	33.64
Young firm (age ≤ 6)	0.068	0.251	0.060	0.237	0.073	0.260	0.123	0.328
Credit rating	2.303	0.507	2.306	0.507	2.253	0.463	2.405	0.591
Export active	0.482	0.500	0.411	0.492	0.649	0.478	0.652	0.477
Located in eastern Germany	0.363	0.481	0.365	0.481	0.352	0.478	0.371	0.484
Part of firm group	0.274	0.446	0.266	0.442	0.304	0.460	0.268	0.443
Share of sales with main product	0.734	0.240	0.752	0.233	0.688	0.249	0.700	0.254
Prior product innovation	0.300	0.458	0.186	0.389	0.564	0.496	0.581	0.494
Prior process innovation	0.223	0.416	0.147	0.354	0.395	0.489	0.416	0.494
Innovation intensity	0.040	0.107	0.022	0.080	0.075	0.138	0.091	0.159
Continuous R&D activity	0.303	0.460	0.178	0.383	0.603	0.490	0.587	0.493
Observations	3630		2551		769		310	

In a second step, we apply two separate Probit regressions to determine the characteristics of firms which report to be financially constrained and would take either additional cash or additional cash and loans. The results of this exercise are shown in Table 2. Similar, to the results in Table 1, we find strong results that young firms are more likely to be constrained by

both their equity and also their access to loans as they are more likely to use either of these financing options for innovation than older firms.

Somewhat surprisingly, we do not find evidence that smaller firms are more likely to be constrained in the sense of our survey experiment. Thus, we do not find any statistical evidence that smaller firms are more likely to invest into innovation with additional resources. The results seem to be dominated by the age of the firm, all else constant.

Table 2: Probit regression results on financial constraints

	(1) Windfall profits	(2) Cheap loan
Small firms	-0.040	-0.078
	(0.062)	(0.081)
Young firms	0.267***	0.311***
	(0.094)	(0.111)
Credit rating	0.123**	0.273***
	(0.052)	(0.061)
Export active	0.152**	0.081
	(0.062)	(0.080)
Part of firm group	-0.204***	-0.173**
	(0.063)	(0.083)
Share of sales with main product	-0.226**	-0.097
	(0.105)	(0.137)
Prior product innovation	0.431***	0.288***
	(0.066)	(0.088)
Prior process innovation	0.369***	0.259***
	(0.062)	(0.077)
Innovation intensity	0.848***	0.718***
	(0.259)	(0.259)
Continuous R&D activity	0.683***	0.291***
	(0.070)	(0.092)
Constant	-1.285***	-2.379***
	(0.229)	(0.312)
Joint significance of		
Industry dummies (X^2-value)	26.453	15.606
Federal state dummies (X^2-value)	13.197	20.617
Pseudo R-squared	0.192	0.115
Log likelihood	-1784.693	-936.906
Observations	3630	3630

Notes: Standard errors in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.

Furthermore, we find strong evidence that the financial constraints rather occur at the intensive margin and not at the extensive margin. All four variables that are directly related to innovation activity at the firm are associated with positively estimated coefficients (product innovation, process innovation, innovation intensity and continuous R&D activity). Therefore,

it does not seem to be the case that many firms which are not innovating at all have promising ideas for innovation. Restrictions on equity and access to the financial market appear to be more binding on companies that are already investing in innovation. Interestingly, there is no additional statistically significant effect of the set of sector dummies. These are not jointly significant according to X^2 tests. It is often reported in the literature that especially high-tech companies are subject to financial constraints (e.g. Himmelberg and Petersen 1994). In our regression, however, possible sectoral effects seem to be completely absorbed by our control variables on R&D and innovative activity of the firm. We therefore find no evidence that firms in high-tech sectors in particular are constrained, but rather that capital market restrictions occur at the intensive margin regardless of the sector.

Finally, we find the expected sign of the credit rating. The worse the financial position of the firm (higher value of the credit rating index), the more likely the firm is to report additional innovation investment upon the receipt of windfall profits and access to loans. If there were no capital market failures, we would have expected that, conditional on the credit rating, no other covariates would turn out to be significant in the regressions. Thus, the sign and significance of the rating variable support the validity of our survey measures for capturing firms' financing constraints for innovation. Consequently, we conclude that capital market restrictions are present and that they apply in particular to young, innovative companies.

4.2 Robustness tests

In further estimations, we also accounted for possible group-wise heteroscedasticity by modeling the variance with a set of industry dummies and indicator variables for small and young firms. We only found very weak evidence on heteroscedasticity and the results reported above do basically not change in any noteworthy form. We thus omit a detailed presentation of these models. We also estimated the two equations jointly as a bivariate Probit model, where possible correlation of the error terms can be exploited to gain efficiency. As the credit dummy

is only equal to one conditional on the equity dummy taking unit value, we have by construction a correlation among equations. The estimations lead to a small reduction in estimated standard errors in the regression, but these are not large. Therefore, all results reported above hold, and we omit a detailed presentation of the bivariate Probit estimations.

4.3 Extrapolations of financing constraints to the population

In the sample, about 29.7% of the firms indicate that they would undertake additional innovation activities if they would receive windfall profits or equity. However, only 8.5% of the firms would also innovate if they could get a cheap loan. This implies in turn that less than a third of financially constrained firms would expect that their forgone innovation activities because of financial constraints have only an expected marginal return rate that is between the cost of internal capital and a cheap loan - thus relatively small private returns. We therefore conclude that the majority of firms in the economy can actually implement important innovation projects.

In order to get an idea about the macroeconomic implications of these survey results, we extrapolate from the sample and split them by innovating firms and non-innovating firms (see Table 3). According to Behrens et al. (2017) the target population of the survey amounted to 277,600 firms. In our sample, 57% of the firms are classified as innovators. If we extrapolate from the survey responses to the population, we find that 127,919 firms innovated, that is, they had at least one product or process innovation in the recent three years before the survey data collected, had ongoing innovation activities or had abandoned innovation projects during the corresponding three years.

In the sample, 31% of the firms reported that they would have invested into (additional) innovation projects if they had received windfall profits. This amounts to a total of 62,952 firms in the population. The confidence interval for this population estimate is [56,432; 69,474]. When looking at the innovating companies, we find that the windfall profits would have a

higher effect at the intensive margin. 50,491 firms that would invest into innovation undertake other innovation projects that are financed without the windfall profits. The effect at the extensive margin is much smaller: only about 12,462 (= 62,953 - 50,491) firms of the pool of current non-innovators would take up innovation project if they would obtain windfall profits.

When looking at firms that would undertake (additional) innovation projects with cheap loans, the numbers are much smaller. In the sample, 11% of all firms, and 16% of innovators report affirmative. This amounts to a total of only 24,207 firms, among them 18,353 innovators. Thus, only about 38% of firms that report they would undertake innovation project with extra financial resources, would do that if these extra resources have a price that is larger than internal funds but still relatively low. Also, we find that the larger effect is at the intensive margin as 18,353 of the 24,207 firms are already having other innovation projects.

We find similar relationships for young firms. In the sample, 7% of the firms are young, i.e. not older than five years. 39% of these would have conducted more innovation projects if they would receive windfall profits. 18% of them, i.e. almost every second company would even use a loan to conduct their non-implemented innovation projects. In terms of extrapolated numbers, these sample data imply that out of 17,476 firms, 4,069 can be classified as financially constrained by their equity. However, in these young firms the financial constraints seem to be even more severe than in the subsample of innovators, as 83% (3,391 out of 4,069) would also use a loan to implement their projects.

Generally, we conclude that roughly about 2/3 of firms indicating that they are financially constrained in their innovation activity, actually do not have project ideas which have a high expected private economic return. This is concluded from the fact that these firms do not indicate that they would undertake these project with resources that are freely available but instead have some positive but still low price. In 2014, the average cost of a business loan was around an interest rate of about 2.5% (European Central Bank 2021). The expected return on sales of forgone innovation projects does therefore not seem high. In the survey, the companies

also report their return on sales, and it amounts on average to 6.1% in the population. These figures therefore do not suggest that firms are on average drastically hampered in their innovation efforts. The consequences of financial constraints would be much more alarming if the forgone returns to innovation are larger than the average returns on sales. As the expected average marginal rates of return of additional innovation projects seems to be below 2.5% for the majority of firms (as these would not use a loan to finance the innovation activity), the capital market imperfection seems not to be severe; at least not in Germany in the year 2014.

Table 3: Sample statistics and extrapolated numbers of (financially constrained) firms and innovators

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Sample means of dummy variables			Extrapolated number of firms in population			95% confidence interval of extrapolation		
	All firms	Innovators	Young firms	All firms	Innovators	Young firms	All firms	Innovators	Young firms
Sample / Population	1	0.57	0.07	277,600	127,919	17,476	[262,623; 292,577]	[120,086; 135,751]	[13,479; 21,473]
Invest if windfall profits received	0.31	0.47	0.39	62,953	50,491	4,069	[56,432; 69,474]	[45,283; 55,699]	[2,501; 5,636]
Invest with cheap loan	0.11	0.16	0.18	24,207	18,353	3,391	[19,559; 28,855]	[14,344; 22,363]	[1,610; 5,171]

5 Results on characteristics of non-implemented projects

5.1 Descriptive analysis on project characteristics

Both the descriptive analysis using extrapolations to the population and the regressions on (additional) innovation investments through windfall profits or loans allow to make judgements about the forgone marginal revenues of not implemented innovation projects because of limited, internal financial resources and also lacking access to external resources. These analyses therefore shed light on the private returns to innovation. We also investigate the type of projects that were not implemented to the extent possible with survey data, since policy makers are also interested in social returns to innovation projects. These are of particular importance as the economic literature suggests that they are often significantly higher than private returns. We employ four variables describing some project characteristics and the firms were asked whether they partly or fully apply to the non-implemented projects: (i) high technological intent, (ii) high market uncertainty, (iii) high marketability, and (iv) entering new markets.

A high technological intent may have high social returns as a project at the forefront of technological feasibility may trigger numerous subsequent follow-on research projects. High market uncertainty may reflect something similar, i.e. the project is challenging and involves radically new ideas and innovative features. A successful implementation may also trigger subsequent innovation projects. A high marketability may indicate that both private and social returns will be high, once the project has been successfully completed and it reaches the market. Entering new markets may reflect social returns in the best Schumpeterian way. Either the firm creates a totally new product for which consequently no market existed before, or it enters a market and is challenging incumbent firms. In both situation, total welfare will most likely be improved. A new market creates both, new producer surplus and consumer surplus. Moreover, a newly challenged market will intensify competition and this will most likely increase consumer surplus.

Descriptive statistics of the variables are presented in Table 4. The results are striking. If one reads the table from left to right, i.e. from no constraints to internal constraints and then to both internal and external constraints, the scores of the dummy variables always increase. This implies that the more constrained the firms are, the more likely they were not able to implement project promising in both dimensions, private and social returns.

Table 4: Descriptive statistics of not-implemented project characteristics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	All firms		No constraints		Only internal		Internal & external	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
High technological intent								
Partly applies	0.028	0.164	0.005	0.071	0.051	0.220	0.158	0.365
Fully applies	0.024	0.153	0.006	0.076	0.047	0.211	0.116	0.321
High market uncertainty								
Partly applies	0.026	0.158	0.006	0.079	0.039	0.194	0.152	0.359
Fully applies	0.023	0.149	0.006	0.076	0.049	0.217	0.094	0.292
High marketability								
Partly applies	0.030	0.171	0.006	0.079	0.060	0.237	0.152	0.359
Fully applies	0.016	0.124	0.004	0.059	0.012	0.108	0.126	0.332
Entering New Markets								
Partly applies	0.023	0.151	0.006	0.079	0.043	0.203	0.116	0.321
Fully applies	0.023	0.149	0.003	0.052	0.038	0.191	0.148	0.356
Observations	3630		2551		769		310	

5.2 Multiple regression analysis on project characteristics

Next, we run Ordered Probit regressions in which each of the project characteristics in Table 4 are applied as dependent variable. The values of these variables range from does not apply (1) over partly applies (2) to fully applies (3). Thus, the higher the value of the variable, the more likely the respective characteristic applies. Our main explanatory variables are ‘Windfall profits’ and ‘Cheap loan’ and those will inform us about the likelihood that a non-implemented project would have been expected to have a specific characteristic. Thus, a positive coefficient for ‘Windfall profits’ when ‘High market uncertainty’ is the dependent variable, implies that firms which report that they would invest their additional cash into innovation were more likely to have a project in their portfolio which has this specific characteristic. The interpretation for the coefficient ‘Cheap loan’ is similar. However, it has to be taken into account that firms that answer to use cheap loans for innovation would have also used windfall profits for this type of

project. Thus, 'Cheap loan' is implicitly an interaction term and thus both coefficients have to be added up. This, in turn, allows conclusions to be drawn about what types of projects are most likely to be undertaken by a firm that would take advantage of a cheap loan for innovation.

The results of the described exercise are shown in Table 5. Again, we observe that the more constrained the firms are, the more likely they were not able to implement projects promising in both dimensions, private and social returns. As both coefficients of windfall profits and loans are positive and statistically significant in all regressions, we see that the firms that would invest into innovation with additional budget seem to have meaningful, rewarding projects in their portfolio that remained unimplemented so far. As the loan coefficient has to be added to the windfall profit coefficient we can also conclude that the firms prepared to take up a cheap loan have even more promising projects on all dimensions in their portfolios. While these results, on the one hand, reaffirm the credibility of the constraint variables obtained from our survey instrument, they also show that the more challenging projects for the firm, such as one with high market uncertainty and high technological intent, are the ones that might not be implemented due to financial constraints. Also projects that would open new markets, and thus may reflect destructive innovation in the Schumpeterian sense, are more likely not to be implemented if firms are constrained by internal resources or even less likely if they are also constrained by external resources.

Unfortunately, we cannot interpret the magnitudes of the coefficients in some economic perspective in the case of Ordered Probit models with unknown threshold values. For example, in Column 8 of Table 5, we find that the underlying index of 'Entering new markets' is 0.801 higher for firms that are internally constrained (those indicating they would use 'windfall profits' for the implementation of additional innovation projects) than for those who are not constrained. This implies that firms, which are not internally constrained had either no or less non-implemented projects that would promise the entry into new markets upon project completion. For firms that also report that they would have used a 'Cheap loan' to implement

projects, the project score for entering new markets would even be 0.805 + 0.801 higher than for non-constrained firms. Unfortunately, we cannot transform this score into an expected probability and extrapolate this with an associated number of forgone projects that would create new market entry without further information on either the variance or the mean of the underlying distribution, and these parameters cannot be identified in an ordered Probit model with unknown threshold values.

Regarding the control variables, we find some additional meaningful results. First, small firms are more likely to have projects in their portfolio that have not yet been implemented. Second, the credit rating has a positive coefficient and that is in line with our expectations. The higher the credit rating score (i.e. the worse is the creditworthiness of the company), the higher are the scores of the non-implemented innovation projects. We interpret this finding such that the available financing options become sooner more expensive, if available at all, than for other firms. Bad credit ratings result in higher likelihood that actually both privately and socially promising projects are not implemented. This is in line with findings of Czarnitzki and Hottenrott (2011a, b) on credit ratings in the context of innovation. Moreover, the innovation intensity has a positively estimated coefficient, which again shows that the constraints are more likely to be binding at the intensive margin. Firms that devote more resources to innovation are more likely to experience that they cannot implement promising projects.

Table 5: Ordered Probit for each innovation project characteristic variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	High technological intent		High market uncertainty		High marketability		Entering New Markets	
Windfall profits	0.985***	0.871***	0.907***	0.745***	0.832***	0.718***	0.968***	0.801***
	(0.095)	(0.111)	(0.094)	(0.109)	(0.100)	(0.119)	(0.100)	(0.118)
Cheap loan	0.642***	0.635***	0.587***	0.616***	0.903***	0.919***	0.763***	0.805***
	(0.094)	(0.098)	(0.097)	(0.101)	(0.098)	(0.105)	(0.099)	(0.105)
Small firms		0.424***		0.336***		0.446***		0.557***
		(0.112)		(0.107)		(0.124)		(0.113)
Young firms		-0.036		-0.005		0.188		0.051
		(0.146)		(0.148)		(0.140)		(0.156)
Credit rating		0.330***		0.299***		0.355***		0.316***
		(0.066)		(0.065)		(0.071)		(0.073)
Export active		0.061		0.038		-0.018		0.114
		(0.108)		(0.105)		(0.112)		(0.112)
Part of firm group		-0.036		-0.066		0.099		0.046
		(0.106)		(0.106)		(0.112)		(0.107)
Share of sales with main product		0.265		0.117		0.020		0.043
		(0.165)		(0.174)		(0.179)		(0.181)
Prior product innovation		-0.061		0.050		0.134		0.242**
		(0.113)		(0.110)		(0.122)		(0.120)
Prior process innovation		0.173*		0.080		0.165		0.144
		(0.099)		(0.101)		(0.102)		(0.101)
Innovation intensity		0.976***		0.406		0.486		0.579**
		(0.308)		(0.292)		(0.307)		(0.291)
Continuous R&D activity		0.317***		0.444***		0.187		0.229*
		(0.123)		(0.126)		(0.127)		(0.127)
Joint significance of								
Industry dummies (X^2-value)		30.481*		30.432*		19.195		33.693**
Federal state dummies (X^2-value)		30.478**		33.841***		691.473***		38.093***
Pseudo R-squared	0.175	0.246	0.153	0.222	0.198	0.271	0.194	0.272
Log likelihood	-717.642	-655.133	-696.495	-639.985	-626.145	-569.066	-639.137	-577.553
Observations	3630	3630	3630	3630	3630	3630	3630	3630

Notes: Standard errors in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.

6 Conclusion

We have conducted a survey experiment on the existence and relevance of financial constraints for innovation. We find a number of results that are relevant for both scholarly literature and technology policy. The main results can be summarized as follows.

First, in conventional surveys many firms indicate that they suffer from financial constraints. Our first part of the survey experiment which is in line with thoughts by Hall (2008) and comparable to an implementation by Hottenrott and Peters (2012) also reveals this: 23% (39%) of all (innovative) firms in German manufacturing and business service sectors report that they would conduct additional innovation projects if they would receive windfall profits.

Second, however, our extended survey experiment allows inferring about the expected marginal returns of non-implemented innovation projects. To this end, we use the insights gained by also asking the firms whether they would conduct additional innovation projects if they had access to cheap loans. At the time of the survey, the average interest rate for business loans had been about 2.5%. We find that the majority of constrained firms would not conduct innovation project if they could obtain a cheap loan but only when they get windfall profits. We thus conclude that for the majority of firms the expected profit margin of additional projects would have been below 2.5% and thus far below the firms' average return on sales of 6.1%, which is reported in the survey. Only 9% (13%) of all (innovative) firms seems to shelf innovation projects that have a higher expected return than 2.5% as these would also implement further projects if they could obtain a cheap loan. We therefore conclude that financial constraints might be present in many firms, but only in a minority of firms these seem to lead in economically significant forgone marginal returns of innovation through non-implemented innovation projects.

Third, we find evidence that mainly young firms and innovative firms are those that are financially constrained. While these findings reflect stylized facts from the literature, we believe

they are noteworthy as we obtain them with a new methodology and therefore even strengthen previous results. In contrast to existing evidence, we do not find a clear pattern regarding firm size, however. We expected that micro-sized or small firms might be particularly constrained, but this does not turn out in our analysis. The result on financial constraints is determined mainly by the general creditworthiness of the company, its age and the constraints show at the intensive margin, i.e. in firms that are innovation-active or innovation-intensive already.

Fourth, we add evidence from qualitative measures of non-implemented projects to further characterize forgone returns of innovation returns in the economy. Our results allow concluding that the lost private and social returns of projects seem higher in those firms that would conduct innovation projects if they received windfall profits than in firms that would use additional resources differently. While this may be expected, our findings also show that these forgone returns are likely to be even be higher in firms that would implement project also if they receive a cheap loan, i.e. additional financial resources at positive marginal cost in contrast to zero as it would be the case with windfall profits.

Our results lead to important policy implications. On the one hand, the problem of financing constraints for innovation may be somewhat overestimated in existing literature and contemporaneous policy, since a large share of firms would use extra money for rather low valued projects. This could indicate that existing policy programs to support innovation are overshooting the mark when applying a scattergun approach. The results also show that non-innovative companies do not seem to be a promising primary target group for innovation policy. Public funding agencies often undertake initiatives to reach companies with their subsidy programs that are not their "clients" yet. As our results reveal that the most relevant financial constraints do not appear at the extensive margin (i.e. not in non-innovating firms), but mainly in firms that are already innovation-active to a certain extent, enlarging the penetration of technology policy in the firm population does not seem to be socially rewarding.

On the other hand, caution has to be paid as a small fraction of firms has projects at hand, which are not executed but may lead to a high expected private and social returns. This in turn leads to a valuable justification for public innovation support programs. Our study reveals that the possible target group are young, innovative companies. These results are confirming some prior literature suggesting that the group of "Young Innovative Companies" (YICs) are possibly most constrained but may contribute significantly to economic growth if their potential can be released (cf. Veugelers 2008, Schneider and Veugelers 2010, 2018, Czarnitzki and Delanote 2013).

As our results suggest that young firms are mainly constrained at the intensive margin, a suitable policy should not attempt to push non-innovative companies into the realm of innovation, but instead allow innovative companies to intensify their activities. While this can be achieved with direct R&D grant programs a public funding agency will always face the problem of selecting the "right" projects. Commonly used R&D tax credit programs do not involve a selection problem, but often require positive profits that young firms might rarely have and also refund just a relatively small share of R&D efforts ex-post. Young firms might not be able to invest initially and the tax credit share that is refunded might not suffice to fund a whole new project but just minor increments to existing projects. Instead capital market restrictions may be better mitigated by

(i) better access to loans through promoting the use of intellectual property (IP) as loan collateral. YICs might have gone through inventive processes that led to patent application but lack resources to bring their inventions to the market. The IP could thus be used as access to capital. While this market for IP is known, it is not frequently used in banking practice yet (cf. Hochberg et al., 2018, Mann, 2018). A possible public loan guarantee program could incentivize firms and banks to utilize IP in loan negotiation more than in current business practice;

(ii) equity investment incentives through tax breaks and public loan guarantees might overcome the selection problem in grant schemes, if a policy program is carefully targeted. An example is possibly the Italian Start Up Act that is targeted at young firms that are either required to own intangible assets such as patents or exclusive licenses, or have to be highly R&D intensive (cf. Giraudo et al., 2019, Biancalani et al., 2021).

(iii) R&D collaboration with (larger) firms or other organization (cf. Czarnitzki and Hottenrott, 2017), and governments could publicly support such alliances.

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Appendix A – Descriptive statistics

Table A1: Distribution of sample firms across industries

Name	NACE Rev. 2.0 code	Firms	Percentage share
Mining	5-9, 19, 35	129	3.554
Food/Tobacco	10-12	155	4.270
Textiles	13-15	133	3.664
Wood/Paper	16-17	135	3.719
Chemicals	20-21	109	3.003
Plastics	22	107	2.948
Glass/Ceramics	23	83	2.287
Metals	24-25	269	7.410
Electrical equipment	26-27	244	6.722
Machinery	28	196	5.399
Retail/Automobile	29-30	78	2.149
Furniture /Toys/Medical technology/Maintenance	31-33	229	6.309
Energy / Water	36-39	179	4.931
Wholesale	46	133	3.664
Transport equipment/ Postal service	49-53, 79	255	7.025
Media services	18, 58-60	159	4.380
IT/Telecommunications	61-63	200	5.510
Banking, insurance	64-66	108	2.975
Technical services/R&D services	71-72	271	7.466
Consulting/Advertisement	69, 70.2, 73	203	5.592
Business-related services	74, 78, 80-82	255	7.025
Total		3630	100.00

Table A2: Distribution of sample firms across federal states

Name	Firms	Percentage share
Baden-Wuerttemberg	547	15.069
Bavaria	421	11.598
Berlin	318	8.760
Brandenburg	167	4.601
Bremen	28	0.771
Hamburg	59	1.625
Hesse	199	5.482
Lower Saxony	238	6.556
Mecklenburg-Vorpommern	69	1.901
North Rhine-Westphalia	505	13.912
Rhineland-Palatinate	111	3.058
Saarland	34	0.937
Saxony	353	9.725
Saxony-Anhalt	140	3.857
Schleswig-Holstein	77	2.121
Thuringia	219	6.033
Missing	145	3.994
Total	3630	100.00

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