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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 survey experiment to evaluate the existence and degree of financial constraints for R&D. The experiment not only allows for the deduction of the presence of financial constraints but also for evaluating their economic significance. Using data on German companies, we find that financial constraints exist, but their relevance might have been overestimated in the literature. Most R&D projects that have not been implemented because of financial constraints seem to have low expected marginal rates of return. While this finding contrasts with other studies, we also find results that align with the literature: young firms are most constrained, and the constraints occur at the intensive margin, i.e. our results do not suggest that firms are deterred from innovation. Instead, highly innovative companies are restricted by the capital market. Small firms, in particular, had innovation projects in their portfolios that were not implemented.

KEYWORDS

Innovation; R&D; financial constraints; survey experiment

JEL CLASSIFICATION

G30; O30; O31; O32; L21



I. Introduction

The debates about financial constraints for innovation have a long tradition in 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 research and development (R&D) project outcomes. These factors make it difficult for potential lenders to judge the expected returns of the investment. In addition, R&D has a low inside collateral value because the lion's share is wages and, thus, immediately sunk expenses. Therefore, R&D and innovation projects are, if possible, more costly to finance with external capital. Due to this reason, firms might have to rely on internal resources. Since these are not unlimited, financial constraints for innovation occur. These are particularly severe for the innovative activities of small and medium-sized companies (SMEs) (e.g. Chiappini et al. 2022; Schneider and Veugelers 2010). This is detrimental to welfare as innovations are important for economic development and growth (Aghion and Howitt 1992; Castellacci 2023; Jones and Williams 1998). Therefore, policymakers

target financing constraints for innovation in general and those for young and small firms in particular (e.g. Chiappini et al. 2022; Czarnitzki and Delanote 2015; European Commission 2010).

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, Fazzari, and Petersen 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, an extensive literature emerged where scholars tried to utilize different concepts to identify financial constraints (e.g. Farre-Mensa and Ljungqvist 2016; Hall 2002, 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

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(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 innovation projects are not executed and which are facilitated with additional investments.

We exploit information from a comparable hypothetical experiment that was included in the German part of the Community Innovation Survey. Instead of providing firms with additional cash, as suggested by Hall (2008), their intended behaviour is analysed. In this way, we can test for financing constraints and the characteristics of related, not executed innovation projects. 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 several new findings and confirms some expected results from earlier literature. First, we show that the extent of severe financial constraints might be much lower than one could expect. Second, we find that particularly young firms and innovation-intensive firms are financially constrained. Third, by considering further survey information, we show that particularly innovation projects with high social returns might not be implemented because of severe financial constraints. Furthermore, we find that about two-thirds of the firms indicating that they are financially constrained in their innovation activity do not have non-executed projects with high expected private economic returns in their portfolio. Fifth, small firms, in particular, have

innovation projects in their portfolio that have not yet been implemented.

Our paper contributes to several strands of literature. In the area of R&D and innovation, scholars have used credit ratings (Czarnitzki and Hottenrott 2011a, 2011b; Fazzari, Hubbard, and Petersen 2000), loan requests and defaults (Aghion et al. 2012; Piga and Atzeni 2007), government subsidies (Chiappini et al. 2022; Czarnitzki 2006; Hyytinen and Toivanen 2005), 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, Manole, and Kabiri 2019) as well as survey data on hampering factors (Savignac 2008) to identify financing constraints. Moreover, we add to the literature that considers firm characteristics like size and age as decisive for financing constraints (e.g. Beck, Demirgüç-Kunt, and Maksimovic 2005; Egel, Licht, and Steil 1997; Karlsson 2021; Winker 1999) and how this affects the innovation behaviour of these firm types (e.g. Czarnitzki and Hottenrott 2011b; De Blick, Paeleman, and Laveren 2023; Pellegrino 2018).

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 of Hottenrott and Peters (2012), who also build on the experimental idea proposed by Hall (2008). Their work shows that financing constraints rather depend on the innovation capability of firms than the availability of internal funds. 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 questionnaire, 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 binding

financial constraints such that they impede the implementation of projects with expected rates of return 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. We suggest that these projects have societal value as they would, in expectation, contribute to technological progress and create new markets.

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 III describes the data. The empirical results are presented in Sections IV and Section VI concludes.

II. Conceptual background

We mainly build on Howe and McFetridge (1976), David, Hall, and Toole (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 firm's innovative capability (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):

$$MRR = f(IC, RDI, X) \quad (1)$$

A profit-maximizing firm will invest in 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), 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 depends on a firm's creditworthiness (W). This reflects, among other factors, capital structure and available collateral. The MCC function g is determined as

$$MCC = g(IF, K, RDI, W) \quad (2)$$

Figure 1 summarizes the implications of the contextualization above graphically. In the left panel (a), we show a firm with six equal-sized project ideas sorted according to the MRR on the vertical axis. The MRR , 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 costs (MC) for additional projects. Consequently, in the left panel (a) of Figure 1, the firm would, in equilibrium, only use internal funds to finance RDI projects 1 and 2. As the MC for the third project

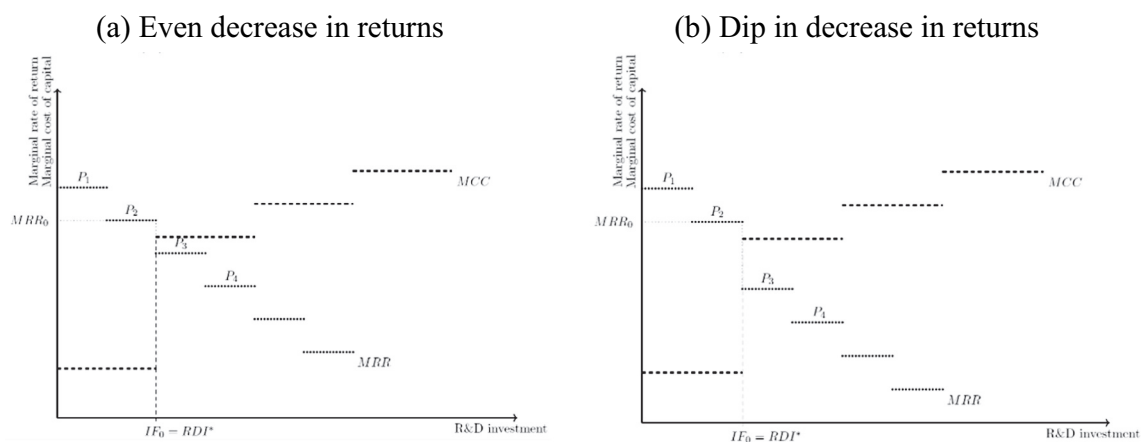


Figure 1. Marginal rate of return and marginal cost curve of research, development and innovation investments.

financed by external resources would exceed the *MRR*, this project would not be implemented.

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

In Figure 2, 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 panels would now implement their third most promising project and finance it with additional internal funds.

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 (a) of Figure 3 would now also obtain a (cheap) loan to invest more into *RDI*. However, the firm in the right panel (b) of Figure 3 suffers from a dip in its innovative capability and, therefore, lower marginal returns from *RDI*. Even with

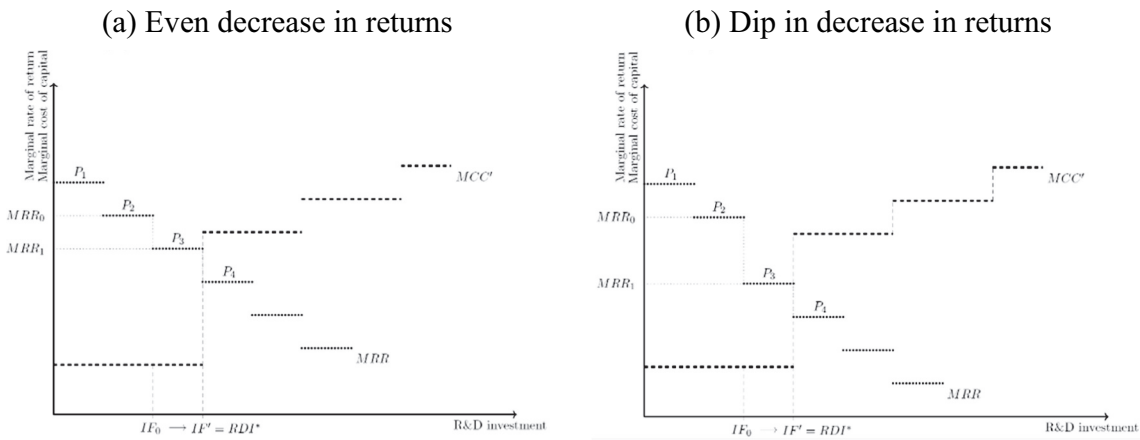


Figure 2. Project implementation with additional internal funds.

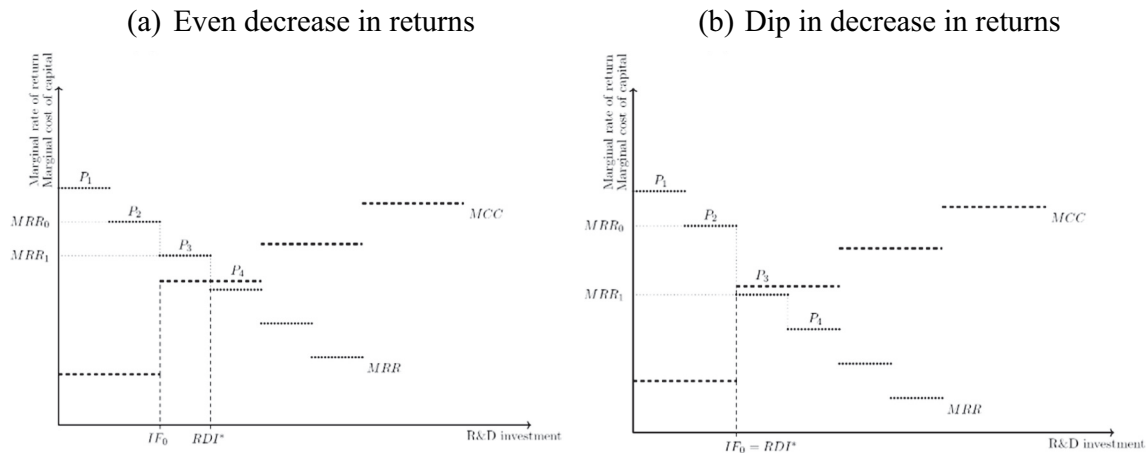


Figure 3. Shock in the lending market reduces marginal costs of capital.

the reduction of the *MCC*, it would not implement the third project as its *MRR* is still not above the now-lowered *MCC*.

Our survey experiment has been set up so that we can identify the scenarios presented in the three figures. We asked both firms whether they would invest in RDI, receive 10% of their returns as windfall profits, and have access to a cheap loan of the same size. This allows conclusions about the private returns of RDI projects not implemented in the business sector. In addition, we also show some indications of possible social returns from such projects in the empirical section. A policy intervention seems justified if social returns are forgone due to capital market imperfections.

III. Data and variables

Data

We use data from the Mannheim Innovation Panel, the German part of the Community Innovation Survey (CIS). The CIS is a biennial exercise coordinated by the Statistical Office of the European Commission and constitutes the official innovation statistics for the EU. It is a representative, large-scale survey designed to measure innovation inputs, innovation outputs and innovation-relevant characteristics of firms and their market environment. The survey is based on the definitions and measurement concepts for innovation data as laid down in the Oslo Manual (OECD and Eurostat 2018).¹ In the 2014 survey, relevant questions on hypothetical investment plans were included.²

The usable subsample for the present study amounts to 3,630 observations. The difference between the general response rate and the sample used in this study is caused by item non-response in variables necessary for the study.³

Survey experiment

After deleting observations 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 the 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“

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. While firms facing no financial constraints are assumed to have no further innovation projects, firms choosing to invest in additional innovation projects are classified as financially constrained. 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

¹A detailed description of the survey and its methodology can be found in Peters and Rammer (2013) and also in Behrens et al. (2017).

²The German CIS 2014 targeted firms with five or more employees in mining, manufacturing, utilities, and a range of business service sectors (wholesale, transportation, information and communication, banks and insurances, professional and technical services, business support services). The survey had a target population of 277,600 firms in the respective sectors of the German economy, and the gross sample size amounted to 22,063 firms. Generally, valid responses were recorded for 6,714 firms, resulting in a response rate of 30%. To evaluate a possible bias between responding and non-responding firms concerning innovation activities, a comprehensive non-response survey was conducted, interviewing 6,163 non-responding firms (40% of all non-responding firms). For data extrapolation, a possible response bias may be corrected using a correction factor for the firms’ sampling weights (see Behrens et al. 2017 for the method used). See, for example, Scheaf et al. (2023) for a discussion of the extent and impact of nonresponse bias in entrepreneurship research.

³In subsection 4.3, we report weighted statistics that are extrapolated from the sample to the target population of the survey, i.e. the German manufacturing sector and business-related services.

would even use a loan to innovate more.⁴ First, firms facing only internal constraints are classified as such if they only choose to invest windfall profits in additional innovation projects. The second group, which faces internal and external financial constraints, consists of firms that would use both windfall profits and a loan for innovation.

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 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 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’.

Control variables

We consider several control variables that allow a judgement about stylized facts on financial constraints as reported in the existing literature. The first obvious control variable is firm size. We

account for the fact that small firms are most likely facing financial constraints (e.g. Beck, Demirgüç-Kuntand, and Maksimovic 2008; Berger and Udell 2002; Czarnitzki 2006) by 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 firm’s age and found it most appropriate to include a dummy variable, ‘Young firm’, for firms up to 6 years after foundation. Furthermore, we include a complete set of sector dummies.⁵ These variables allow conclusions about the stylized fact that small or young firms in high-tech sectors are supposedly the most financially constrained.

In addition, we control for the company’s creditworthiness 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 stems 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.⁶

We add several control variables that reflect the focal firm’s innovation capability and investment level: First, 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, second, innovation capabilities are taken into account by three dummies indicating (i) whether the firm conducts R&D permanently (‘Continuous R&D activity’), (ii) whether the firm has introduced a new product to the market during the recent 3 years (‘Prior product innovation’) and (iii) whether a new process has been implemented in the firm’s production in the last 3 years (‘Prior process innovation’).

Finally, we include other controls: a dummy ‘Part of firm group’ indicates whether the firm is part of a consortium.⁷ In addition, we account for the export activity of firms as this is related to firm financing constraints and firm’s innovation

⁴The way we approach the variable definition aligns with the pecking order of financing, according to Myers and Majluf (1984). This includes firms preferring financing via internal means over credits and over equity financing, which is also found to be true for Germany (e.g. Hummel, Karcher, and Schultz 2013).

⁵See Table A1 in Appendix A for an overview of industry dummy variables and the respective share of firms in each industry.

⁶Note that we do not include a variable measuring collateral as the experimental survey question on access to loans implies its availability already.

⁷Subsidiaries of large parent companies might have access to resources that make them less prone to financial constraints.

behaviour (Bellone et al. 2010; Fassio 2018; Manova 2013). Thus, 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 a company obtains with its most important product or product line in total sales.⁸ In addition to these variables, we also control for the firm’s location. For this purpose, we include a set of federal state dummies.⁹

IV. Results for financing constraints

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. The rating value for the average firm is 2.3,

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

Next, we compare firms reporting that they are not constrained (column 5) and firms that would take additional cash (column 7). It becomes evident that constrained firms are larger, younger, more likely exporters and have a higher innovation capability. Comparing the unconstrained firms to firms that would take additional internal and external financing (column 10) shows the following: The severely constrained 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 to be financially constrained. Moreover, the descriptive statistics imply that firms that would take additional internal or external financing have a weaker rating value, which also indicates a higher degree of financial constraints.

In a second step, we determine the characteristics of firms that report being financially

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)			
	All firms				No constraints		Constraints								
							Only internal		Internal & external						
	Mean	SD	Min	Max	Mean	SD	Mean	SD	(5)=(7)	Mean	SD	(5)=(10)			
Employees	148.488	726.692	1	24600	135.700	654.980	200.607	1014.834	[0.036]	124.429	305.411	[0.765]			
Firm age	31.323	33.797	1	524	32.075	34.652	29.860	30.797	[0.111]	28.768	33.636	[0.112]			
Small firm (less than 50 employees)	0.642	0.479	0	1	0.665	0.472	0.576	0.495	[0.000]	0.616	0.487	[0.085]			
Young firm (age ≤ 6 years)	0.068	0.251	0	1	0.060	0.237	0.073	0.260	[0.184]	0.123	0.328	[0.000]			
Credit rating	2.303	0.507	1	6	2.306	0.507	2.253	0.463	[0.009]	2.405	0.591	[0.002]			
Export active	0.482	0.500	0	1	0.411	0.492	0.649	0.478	[0.000]	0.652	0.477	[0.000]			
Located in eastern Germany	0.363	0.481	0	1	0.365	0.481	0.352	0.478	[0.539]	0.371	0.484	[0.825]			
Part of firm group	0.274	0.446	0	1	0.266	0.442	0.304	0.460	[0.038]	0.268	0.443	[0.953]			
Share of sales with main product	0.734	0.240	0	1	0.752	0.233	0.688	0.249	[0.000]	0.700	0.254	[0.000]			
Prior product innovation	0.300	0.458	0	1	0.186	0.389	0.564	0.496	[0.000]	0.581	0.494	[0.000]			
Prior process innovation	0.223	0.416	0	1	0.147	0.354	0.395	0.489	[0.000]	0.416	0.494	[0.000]			
Innovation intensity	0.040	0.107	0	1	0.022	0.080	0.075	0.138	[0.000]	0.091	0.159	[0.000]			
Continuous R&D activity	0.013	0.069	0	1	0.007	0.050	0.025	0.090	[0.000]	0.033	0.119	[0.000]			
Observations	3630				2551		769		3320			310		2861	

The table shows the descriptive statistics for the sample described in Section III. The values in parentheses in columns 7 and 10 represent the p-values of the test with the null hypothesis indicated in the column heading. The alternative hypothesis is inequality in the respective values.

⁸Less 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 does not require frequent improvements or adaptations.

⁹See Table A2 in Appendix A for an overview of the included federal states and the share of firms included in each category. Table A3 in Appendix A covers a description of the variables used in the analysis.

constrained and would take either additional cash or additional cash and loans. For this purpose, specify the following regression model:

$$\begin{aligned}
 y^* = & \beta_0 + \beta_1 \text{Small firm} + \beta_2 \text{Young firm} \\
 & + \beta_3 \text{credit rating} + \beta_4 \text{Export active} \\
 & + \beta_5 \text{Part of firm group} \\
 & + \beta_6 \text{Share of sales with main product} \\
 & + \beta_7 \text{Prior product innovation} \\
 & + \beta_8 \text{Prior process innovation} \\
 & + \beta_9 \text{Innovation intensity} \\
 & + \beta_{10} \text{Continuous R \& D activity} \\
 & + \sum_{j=1}^{20} \gamma_j \text{Sector}_j + \sum_{k=1}^{16} \delta_k \text{State}_k + \varepsilon
 \end{aligned} \tag{3}$$

with $y = 1$ if $y^* > 0$ and 0 otherwise. We assume the statistical error term to be normally distributed, i.e. $N(0,1)$, and can thus estimate the equation as a Probit model. The dependent variable y is either a dummy variable for taking additional cash in our first regression model, or for taking an additional loan in our second equation.¹⁰

The estimates are shown in Table 2.¹¹ Similar to the results in Table 1, we find that young firms are more likely to be constrained by both their equity and access to loans, as they are more likely to use either of these financing options for innovation than older firms. 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 statistical evidence that smaller firms are more likely to invest in innovation with additional financial resources.¹² The results seem to be dominated by the firm's age, all else constant.

Furthermore, we find strong evidence that the financial constraints occur at the intensive margin rather than the extensive margin. Regarding the intensive 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) in columns (1) and (2) of Table 2. Therefore, it does not seem to be the case that many firms that are not innovating at all have promising ideas for innovation. This implies that financing constraints are not binding at the extensive

Table 2. Probit regression results on financial constraints.

	(1) Windfall profits	(2) Cheap loan
Small firm	-0.040 (0.062)	-0.078 (0.081)
Young firm	0.267*** (0.094)	0.311*** (0.111)
Credit rating	0.123** (0.052)	0.273*** (0.061)
Export active	0.152** (0.062)	0.081 (0.080)
Part of firm group	-0.204*** (0.063)	-0.173** (0.083)
Share of sales with main product	-0.226** (0.105)	-0.097 (0.137)
Prior product innovation	0.431*** (0.066)	0.288*** (0.088)
Prior process innovation	0.369*** (0.062)	0.259*** (0.077)
Innovation intensity	0.848*** (0.259)	0.718*** (0.259)
Continuous R&D activity	0.683*** (0.070)	0.291*** (0.092)
Constant	-1.285*** (0.229)	-2.379*** (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

The table shows probit regressions for the determinants of internal (windfall profits) and external (cheap loan) financing constraints. Each regression includes a set of explanatory variables as described in Section III, industry dummies, and federal state fixed effects. Huber-White standard errors are shown in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.

¹⁰We have some priors regarding the coefficients to be estimated. We expect β_1 and β_2 to be positive because both small and young firms might be more financially constrained than larger or older firms. The coefficient β_3 is expected to be positive, as a higher credit rating implies a worse financial position of the firm. The coefficient estimate of this variable may also serve as validation if our variables from the survey experiment are sound. The coefficient estimate should definitely be positive if the dependent variables are supposed to measure financial constraints. The coefficient β_2 should be negative if firms that are part of the group are less financially constrained as they can be backed up by their respective parent companies. We expect positive signs for all coefficient estimates from β_7 to β_{10} because the more innovative firms could be more financially constrained. We have no priors for the coefficient estimates of the sector and state dummies but consider them as important controls.

¹¹We provide logit estimations with odds ratios in Appendix B, Table B1. In further estimations, we also accounted for possible group-wise heteroscedasticity by modelling 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 the 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.

¹²In additional tests, we split the size variable into two indicators related to micro-sized firms (0–9 employees) and small firms (10–49 employees). These estimations led to comparable results.

margin. Restrictions on equity and access to the financial market appear to be more binding on companies 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. The literature often reports that 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 the firm's innovative activity. 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 industry.

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 receiving 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 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 apply particularly to young, innovative companies.

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 that less than a third of financially constrained firms would expect their forgone innovation activities to have an expected marginal return rate between the cost of internal capital and a cheap loan – i.e. relatively small private returns. We conclude that most firms in the economy can actually implement important innovation projects.

To understand the macroeconomic implications of these survey results, we extrapolate from the sample and split the firms into innovating and non-innovating (see Table 3). According to Behrens et al. (2017), the survey's target population 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 3 years before the survey data was collected, had ongoing innovation activities, or had abandoned innovation projects during the corresponding 3 years.

In the raw sample, 31% of the firms reported that they would have invested in (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 in 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 projects if they would obtain windfall profits.

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]

The table shows sample statistics and extrapolated numbers of (financially constrained) firms and innovators. Standard errors in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.

The numbers are much smaller when looking at firms that would undertake (additional) innovation projects with cheap loans. 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 projects with extra financial resources would do that if these additional resources have a price larger than internal funds, but that is still relatively low. Also, we find that the larger effect is at the intensive margin, as 18,353 of the 24,207 firms already have performed other innovation projects.

We find similar relationships for young firms. In the sample, 7% of the firms are young, i.e. at most 5-years old. If they received windfall profits, 39% of these would have conducted more innovation projects. Eighteen percent 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 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, roughly 2/3 of firms indicate that they are financially constrained in their innovation activity and do not have project ideas with a high expected private economic return. This is concluded from the fact that these firms do not indicate that they would undertake projects with some positive but still low prices with freely available resources. In 2014, the average cost of a business loan was around an interest rate of about 2.5% (European Central Bank 2021). Therefore, the expected return on sales of forgone innovation projects seems low. In the survey, the companies also report their return on sales, which amounts on average to 6.1% in the population. Therefore, these figures do not suggest that firms are drastically

hampered in their innovation efforts on average. The consequences of financial constraints would be much more alarming if the forgone returns to innovation were larger than the average returns on sales. As the expected average marginal rates of return of additional innovation projects seem 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.

V. Results on characteristics of non-implemented projects

Descriptive analysis related to project characteristics

The descriptive analysis using extrapolations to the population and the regressions on (additional) innovation investments through windfall profits or loans allow us to judge the forgone marginal revenues of not implemented innovation projects because of limited internal financial resources and lack of access to external resources. These analyses, therefore, shed light on the private returns to innovation. We also investigate the type of projects not implemented to the extent possible with survey data since policymakers are also interested in social returns to innovation projects. These are particularly important as the economic literature suggests they are often significantly higher than private returns. We employ four variables describing some project characteristics, for which 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.¹³

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

¹³A high technological intent (i) may have high social returns as a project at the forefront of technological feasibility may trigger numerous follow-on research projects. High market uncertainty (ii) 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. High marketability (iii) may indicate that both private and social returns will be increased once the project has been successfully completed and reached the market. Entering new markets (iv) 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 challenges incumbent firms. In both situations, 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, which will most likely increase consumer surplus.

Table 4. Descriptive statistics of not-implemented project characteristics.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	All firms		No constraints		Constraints					
	Mean	SD	Mean	SD	Only internal			Internal & external		
					Mean	SD	(3)=(5)	Mean	SD	(3)=(8)
High technological intent										
Partly applies	0.028	0.164	0.005	0.071	0.051	0.220	[0.000]	0.158	0.365	[0.000]
Fully applies	0.024	0.153	0.006	0.076	0.047	0.211	[0.000]	0.116	0.321	[0.000]
High market uncertainty										
Partly applies	0.026	0.158	0.006	0.079	0.039	0.194	[0.000]	0.152	0.359	[0.000]
Fully applies	0.023	0.149	0.006	0.076	0.049	0.217	[0.000]	0.094	0.292	[0.000]
High marketability										
Partly applies	0.030	0.171	0.006	0.079	0.060	0.237	[0.000]	0.152	0.359	[0.000]
Fully applies	0.016	0.124	0.004	0.059	0.012	0.108	[0.007]	0.126	0.332	[0.000]
Entering New Markets										
Partly applies	0.023	0.151	0.006	0.079	0.043	0.203	[0.000]	0.116	0.321	[0.000]
Fully applies	0.023	0.149	0.003	0.052	0.038	0.191	[0.000]	0.148	0.356	[0.000]
Observations	3630		2551		769			3320		
								310		2861

The table shows the descriptive statistics for the sample described in Section III. The values in parentheses in columns 7 and 10 represent p-values of the test with the null hypothesis indicated in the column heading. The alternative hypothesis is inequality in the respective values.

dummy variables always increase. This implies that the more constrained the firms are, the more likely they cannot implement projects promising in both dimensions, private and social returns.

Multiple regression analysis on project characteristics

Next, we run Ordered Probit regressions of the following form to analyse the determinants of each project characteristic.

$$\Pr(\text{characteristic}_{i=j}) = \Pr \left(\begin{array}{l} \kappa_{j-1} < \beta_0 \\ +\beta_1 \text{Windfall profits} \\ +\beta_2 \text{Cheap loan} + \gamma X \\ +u_i < \kappa_j \end{array} \right) \quad (4)$$

Thereby, each of the project characteristics in Table 4 is applied as the dependent variable 'characteristic'. The values j of these variables range from does not apply (1) over partly applies (2) to fully applies (3). Thus, the higher the variable's value, the more likely the respective characteristic applies. The β and γ coefficients are estimated together with the threshold values κ . Thereby the probability that the value j of characteristic i is observed is determined by the probability that the estimated parameters are within the interval $[\kappa_{j-1}; \kappa_j]$. In addition to the

control variables X , for which we use the same set of variables as in the Probit regressions above, our main explanatory variables of interest are 'Windfall profits' and 'Cheap loan'. These will inform us about the likelihood that a non-implemented project would have been expected to have a specific characteristic.¹⁴

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 cannot implement projects promising in both dimensions, private and social returns. The windfall profits and cheap loan coefficients are positive and statistically significant in all regressions. Therefore, the firms that would invest in innovation with additional budget seem to have meaningful, rewarding projects in their portfolio that have 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. On the one hand, these results reaffirm the credibility of the constraint variables obtained from our survey instrument. On the other hand, they also show that the more challenging projects for the firm, such as ones with high market uncertainty and high

¹⁴Thus, a positive coefficient for 'Windfall profits' when 'High market uncertainty' is the dependent variable implies that firms that report that they would invest their additional cash into innovation were more likely to have a project in their portfolio with this specific characteristic. The interpretation for the coefficient 'Cheap loan' is similar. However, it has to be considered that firms that answer to using cheap loans for innovation would have also used windfall profits for this type of project. Thus, 'Cheap loan' is implicitly an interaction term, and therefore both coefficients must be added. 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.

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*** (0.095)	0.871*** (0.111)	0.907*** (0.094)	0.745*** (0.109)	0.832*** (0.100)	0.718*** (0.119)	0.968*** (0.100)	0.801*** (0.118)
Cheap loan	0.642*** (0.094)	0.635*** (0.098)	0.587*** (0.097)	0.616*** (0.101)	0.903*** (0.098)	0.919*** (0.105)	0.763*** (0.099)	0.805*** (0.105)
Small firms		0.424*** (0.112)		0.336*** (0.107)		0.446*** (0.124)		0.557*** (0.113)
Young firms		-0.036 (0.146)		-0.005 (0.148)		0.188 (0.140)		0.051 (0.156)
Credit rating		0.330*** (0.066)		0.299*** (0.065)		0.355*** (0.071)		0.316*** (0.073)
Export active		0.061 (0.108)		0.038 (0.105)		-0.018 (0.112)		0.114 (0.112)
Part of firm group		-0.036 (0.106)		-0.066 (0.106)		0.099 (0.112)		0.046 (0.107)
Share of sales with main product		0.265 (0.165)		0.117 (0.174)		0.020 (0.179)		0.043 (0.181)
Prior product innovation		-0.061 (0.113)		0.050 (0.110)		0.134 (0.122)		0.242** (0.120)
Prior process innovation		0.173* (0.099)		0.080 (0.101)		0.165 (0.102)		0.144 (0.101)
Innovation intensity		0.976*** (0.308)		0.406 (0.292)		0.486 (0.307)		0.579** (0.291)
Continuous R&D activity		0.317*** (0.123)		0.444*** (0.126)		0.187 (0.127)		0.229* (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

The table shows Ordered Probit regressions for each innovation project characteristic variable. Each regression includes a set of explanatory variables as described in Section III, industry dummies, and federal state fixed effects. Huber-White standard errors are shown in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.

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. 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.¹⁵ This implies that firms that are not internally constrained had either no or less non-implemented projects that would promise 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 higher (0.805 + 0.801) than for non-constrained firms.¹⁶

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 that aligns with our expectations. The higher the credit rating score (i.e. the worse the creditworthiness of the company), the higher the scores of the non-implemented innovation projects. We interpret this finding such that the available financing options (if available) become sooner more expensive than for other firms. Bad credit ratings increase the likelihood

¹⁵It is important to consider that we cannot interpret the magnitudes of the coefficients in some economic perspective in the case of Ordered Probit models with unknown threshold values. We provide ordered logit models with odds ratios in Appendix B, Table B2.

¹⁶It has to be noted that 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.

that privately and socially promising projects are not implemented. This is in line with the 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 difficulties in implementing promising projects.

VI. Conclusion

We have conducted a survey experiment on the existence and relevance of financial constraints for innovation.¹⁷ We find a number of results that are relevant to 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 the 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 projects if they could obtain a cheap loan but only when they get windfall profits. We thus conclude that for most 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%, as reported in the survey. Only 9% (13%) of

all (innovative) firms seem to shelve innovation projects with 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 although financial constraints might be present in many firms, only in a minority of them do these seem to lead to 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. However, in contrast to existing evidence, we do not find a clear pattern regarding firm size. 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 and its age. Moreover, the constraints are present 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 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 higher in firms that would implement the 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. Another finding from this part of the analysis also implies that small firms are more likely to have projects that have not yet been implemented in their portfolio.

¹⁷Although carefully conducted, we cannot state that our survey experiment is free from limitations. We must particularly acknowledge a conceptual difference between the suggested experiment by Hall (2008) and our hypothetical set up. While the experiment suggested by Hall (2008) aims to observe what firms do with additional cash after receiving it, our experiment asks about firms' intentions. Therefore, we cannot rule out that there is a degree of cognitive bias due to the potential discrepancy between intention and actual behaviour (e.g. Chandon, Morwitzand, and Reinartz 2005; Cossette 2014).

Our results lead to important policy implications. On the one hand, the problem of financing constraints for innovation may be overestimated in the existing literature and contemporaneous policy since a large share of firms would use the extra money for rather low-valued projects. This could indicate that existing policy programmes 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 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 that are not executed but may lead to high expected private and social returns. This leads to a valuable justification for public innovation support programmes. Our study reveals that the possible target group is young and innovative companies. These results confirm 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. Czarnitzki and Delanote 2013; Nilsen, Raknerud, and Iancu 2020; Schneider and Veugelers 2010, 2018; Veugelers 2008).

As our results suggest that young firms are mainly constrained at the intensive margin, a suitable policy should refrain from attempting to push non-innovative companies into the realm of innovation but instead allow them to intensify their activities. While this can be achieved with direct R&D grant programmes, a public funding

agency will always face the problem of selecting the ‘right’ projects. Commonly used R&D tax credit programmes do not involve a selection problem, but often require positive profits that young firms might rarely have. Moreover, they refund just a relatively small share of R&D efforts ex-post. Young firms might not be able to invest initially, and the refunded tax credit share 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 by promoting intellectual property (IP) as loan collateral.¹⁸
- (ii) equity investment incentives through tax breaks and public loan guarantees might overcome the selection problem in grant schemes if a policy programme is carefully targeted.¹⁹
- (iii) R&D collaboration with (larger) firms or other organizations (cf. Czarnitzki and Hottenrott 2017), and governments could publicly support such alliances.

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Data availability statement

The data that support the findings of this study are available from the Research Data Centre of the Leibniz Centre for European Economic Research (ZEW), Mannheim, Germany.

¹⁸YICs might have gone through inventive processes that led to patent applications but lacked resources to bring their inventions to the market. Particularly for the later stages of the innovation process, access to finance like bank loans could be important for small and high-tech firms (Giannetti 2012). 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, Serrano, and Ziedonis 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.

¹⁹An example is possibly the Italian Start-Up Act which is targeted at young firms that are either required to own intangible assets such as patents or exclusive licences or have to be highly R&D intensive (cf. Biancalani, Czarnitzki, and Riccaboni 2021; Giraudo, Giudici, and Grilli 2019).

The data can be accessed free of charge by interested scholars for research purposes (including replication studies). Please visit the research data Centre website for further information: <https://kooperationen.zew.de/en/zew-fdz/home>.

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Appendix

Appendix A Descriptive statistics

Table A1. Distribution of sample firms across industries.

Industry name	NACE Rev. 2.0 code	Firm count	Percentage share of firms
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

The table shows the distribution of firms (count and share) over industries. Rev. 2.0 code refers to the Statistical Classification of Economic Activities in the European Community.

Table A2. Distribution of sample firms across federal states.

Name of federal state	Firm count	Percentage share of firms
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

The table shows the distribution of firms (count and share) over federal states.

Table A3. Description of variables used in the analysis.

		(2)	(3)	(4)	(5)
		All firms			
(1)		Mean	SD	Min	Max
	Description				
Employees	A continuous variable that measures the number of employees.	148.488	726.692	1	24600
Firm age	A continuous variable that measures the age of the firm in years.	31.323	33.797	1	524
Dummy small firm (less than 50 empl.)	A dummy variable that takes value 1 if the firm has less than 50 employees, 0 if not.	0.642	0.479	0	1
Young firm (age ≤6)	A dummy variable that takes value 1 if the firm is less than six years old, 0 if not.	0.068	0.251	0	1
Credit rating	A continuous externally calculated credit rating index ranging from 1 (best rating) to 6 (weakest rating)	2.303	0.507	1	6
Export active	A dummy variable that takes value 1 if the firm achieved sales abroad, 0 if not.	0.482	0.500	0	1
Located in eastern Germany	A dummy variable that takes value 1 if the firm is located in eastern Germany, 0 if not.	0.363	0.481	0	1
Part of firm group	A dummy variable that takes value 1 if the firm is part of a firm group, 0 if not.	0.274	0.446	0	1
Share of sales with main product	A continuous variable that measures the share of sales the firm achieves with the main product, ranging from 0 (lowest) to 1 (highest).	0.734	0.240	0	1
Prior product innovation	A dummy variable that takes value 1 if the firm successfully carried out a product innovation in the last three years, 0 if not.	0.300	0.458	0	1
Prior process innovation	A dummy variable that takes value 1 if the firm successfully carried out a process innovation in the last three years, 0 if not.	0.223	0.416	0	1
Innovation intensity	A continuous variable that measures the ratio of innovation expenditures over sales, ranging from 0 (lowest) to 1 (highest).	0.040	0.107	0	1
Continuous R&D activity	A dummy variable that takes value 1 if the firm carries out R&D activities continuously, 0 if rarely or never.	0.013	0.069	0	1
Windfall profits	A dummy variable that takes value 1 if the firm stated that it would use additional windfall profits for the implementation of additional innovation projects, 0 if not.	0.297	0.457	0.000	1.000
Cheap loan	A dummy variable that takes value 1 if the firm stated that it would use an additional cheap loan for investments into innovation projects, 0 if not.	0.085	0.280	0.000	1.000
High technological intent	A categorical variable constructed from the question of whether the firm refrained from implementing innovation projects with the characteristic 'High technological intent/degree of novelty'. Variable realizations are the values 1 (fully applies), 2 (partly applies), or 3 (does not apply).	1.076	0.343	1.000	3.000
High market uncertainty	A categorical variable constructed from the question of whether the firm refrained from implementing innovation projects with the characteristic 'High uncertainty over feasibility/market acceptance'. Variable realizations are the values 1 (fully applies), 2 (partly applies), or 3 (does not apply).	1.071	0.333	1.000	3.000
High marketability	A categorical variable constructed from the question of whether the firm refrained from implementing innovation projects with the characteristic 'High marketability/closeness to client requests'. Variable realizations are the values 1 (fully applies), 2 (partly applies), or 3 (does not apply).	1.061	0.298	1.000	3.000
Entering New Markets	A categorical variable constructed from the question of whether the firm refrained from implementing innovation projects with the characteristic 'Entering new market segments/thematic areas'. Variable realizations are the values 1 (fully applies), 2 (partly applies), or 3 (does not apply).	1.069	0.330	1.000	3.000
Observations			3630		

Appendix B Further results**Table B1.** Logit regression results on financial constraints.

	(1) Windfall profits	(2) Cheap loan
Small firms	-0.083 (0.109)	-0.145 (0.160)
Young firms	0.454*** (0.161)	0.581*** (0.208)
Credit rating	0.218** (0.091)	0.515*** (0.116)
Export active	0.259** (0.109)	0.135 (0.160)
Part of firm group	-0.367*** (0.111)	-0.352** (0.166)
Share of sales with main product	-0.378** (0.183)	-0.193 (0.272)
Prior product innovation	0.710*** (0.112)	0.553*** (0.178)
Prior process innovation	0.618*** (0.105)	0.480*** (0.150)
Innovation intensity	1.464*** (0.452)	1.270*** (0.468)
Continuous R&D activity	1.136*** (0.119)	0.586*** (0.183)
Constant	-2.159*** (0.407)	-4.393*** (0.659)
Joint significance of		
Industry dummies (X^2 -value)	25.836	15.959
Federal state dummies (X^2 -value)	12.481	18.663
Pseudo R-squared	0.191	0.114
Log likelihood	-1787.135	-938.107
Observations	3630	3630

The table shows logit regressions for the determinants of internal (windfall profits) and external (cheap loan) financing constraints. Each regression includes a set of explanatory variables as described in [Section III](#), industry dummies, and federal state fixed effects. Coefficients represent odds ratios. Huber-White standard errors are shown in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.

Table B2. Ordered logit 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*** (0.095)	0.871*** (0.111)	0.907*** (0.094)	0.745*** (0.109)	0.832*** (0.100)	0.718*** (0.119)	0.968*** (0.100)	0.801*** (0.118)
Cheap loan	0.642*** (0.094)	0.635*** (0.098)	0.587*** (0.097)	0.616*** (0.101)	0.903*** (0.098)	0.919*** (0.105)	0.763*** (0.099)	0.805*** (0.105)
Small firms		0.424*** (0.112)		0.336*** (0.107)		0.446*** (0.124)		0.557*** (0.113)
Young firms		-0.036 (0.146)		-0.005 (0.148)		0.188 (0.140)		0.051 (0.156)
Credit rating		0.330*** (0.066)		0.299*** (0.065)		0.355*** (0.071)		0.316*** (0.073)
Export active		0.061 (0.108)		0.038 (0.105)		-0.018 (0.112)		0.114 (0.112)
Part of firm group		-0.036 (0.106)		-0.066 (0.106)		0.099 (0.112)		0.046 (0.107)
Share of sales with main product		0.265 (0.165)		0.117 (0.174)		0.020 (0.179)		0.043 (0.181)
Prior product innovation		-0.061 (0.113)		0.050 (0.110)		0.134 (0.122)		0.242** (0.120)
Prior process innovation		0.173* (0.099)		0.080 (0.101)		0.165 (0.102)		0.144 (0.101)
Innovation intensity		0.976*** (0.308)		0.406 (0.292)		0.486 (0.307)		0.579** (0.291)
Continuous R&D activity		0.317*** (0.123)		0.444*** (0.126)		0.187 (0.127)		0.229* (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

The table shows Ordered Probit regressions for each innovation project characteristic variable. Each regression includes a set of explanatory variables as described in Section III, industry dummies, and federal state fixed effects. Huber-White standard errors are shown in parentheses. *** (**, *) denote a 1% (5%, 10%) significance level.