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Financial constraints: do they matter to R&D subsidy attribution?

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Abstract:

Even though innovation subsidies and financial constraints are two closely related lines of research, the link between them is rather unexplored. This paper is, to our knowledge, the first to explicitly analyse both the allocation of innovation subsidies and their role in alleviating firms' financial constraints. It is not the purpose of the paper to question whether subsidies foster innovation, but rather if: a) subsidies are being correctly allocated to financially constrained firms; b) they effectively reduce financial constraints. We argue that, in addition to the usual "public good" arguments behind the allocation of innovation subsidies, the extent to which firms are able to obtain external funding should not be overlooked. Overall, our results question the allocation and effectiveness of subsidies in alleviating financial constraints of firms willing to innovate. Accordingly, these findings have serious implications on the design of future innovation policy actions.

Keywords: R&D subsidies; Innovation; Financial constraints; Firm-level analysis; Portugal.

JEL Classification: D92; G32; O38; L20.

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1. Introduction

> *"The changes in the economic process brought about by innovation, (...) we shall designate by the term Economic Evolution."*
> *"Capitalism is that form of private property economy in which innovations are carried out by means of borrowed money."*
>
> (Schumpeter, 1939, pp. 86 & 223).

The 2008 financial crisis and subsequent sovereign debt problems hanging over the European Monetary Union countries calls for an increased efficiency of public funding programmes. This paper contributes to the debate on the financing of firms' innovation activities.

There are two key arguments why firms' innovation activities should be subsidised: the "public good" and the "financial market failure" thesis. The former states that there are significant spillover effects associated with innovations, that is, the social return of innovation is higher than its private return. The latter relies on evidence that R&D expenditures and innovation activities are particularly prone to financial constraints (Hall and Lerner, 2010).

Even though the analysis of firms' financial constraints and the extent to which subsidies foster firms' R&D and innovation are two closely related lines of research, the link between them is rather unexplored. Which criteria should prevail when evaluating potential subsidy recipients? On the one hand, one might argue that, regardless of financial constraints, subsidies are desirable as long as they promote innovation. On the other, it seems sensible to say that subsidies should be aimed at financially constrained firms.

In practice, innovation subsidies have different objectives and criteria than other public financial support measures that strictly address financial constraints. While the latter is to reduce financial constraints to promote investment, growth and\or job creation, the former is to promote innovation. However, the point we make in this paper is that regardless of the ultimate policy objective, subsidies should be given to those firms in need. In other words, those firms that have difficulties in accessing finance, which we define here as financially constrained. Only then, can we argue that the "financial market failure" is truly being addressed.

This paper is, to our knowledge, the first to explicitly analyse both the allocation of innovation subsidies and their role in alleviating firms' financial constraints. It is not the purpose of the paper to question whether subsidies foster innovation, but rather if: *a*) subsidies are being correctly allocated to financially constrained firms; *b*) they effectively increase firms' ability to obtain external finance.[1] We argue that, in addition to the usual "public good" arguments behind the allocation of innovation subsidies, the extent to which firms are able to obtain external funding should not be overlooked.

The literature on firms' financial constraints struggles to find a consistent methodology to measure such constraints (Carreira and Silva, 2010). Given that the interest of the paper lies on discerning policy implications, we employ different methodologies to test the robustness of our findings—namely, we resort to *a*) a self-assessed measure; *b*) the MS index (Musso and Schiavo, 2008); *c*) an adaptation of the MS index to encompass different levels of constraints across industries (weighted MS); *d*) the HH index (Hovakimien and Hovakimien, 2009). To conduct our empirical tests, we use a large unbalanced panel of Portuguese firms covering the period 1996-2004. This dataset comprises detailed information on firms' generic characteristics and balance sheets, matched with three waves of the Community Innovation Survey (CIS), which provide additional variables on innovation, subsidies and self-assessed financial constraints.

Overall, our results question the allocation and effectiveness of subsidies in alleviating financial constraints of firms willing to innovate. Accordingly, these findings have serious implications on the design of future innovation policy actions.

The paper is organized as follows. Section 2 overviews what is generally known about the role of innovation subsidies and the existence of firms' financial constraints, as well as it formulates the main hypotheses to be tested. In Section 3 we describe the dataset and methodology used, while the main empirical results can be found in Section 4. Finally, in Section 5 we discuss the main findings, while Section 6 pulls the pieces together and concludes.

[1] As we will see in Section 2.2, there is a large body of literature showing the impact of subsides on firm's innovation

2. Subsidies to Innovation and Financial constraints

2.1. Measuring financial constraints

The empirical analysis of firms' financial constraints can essentially be traced back to the seminal work of Fazzari et al. (1988), who introduced the well-know investment to cash-flow sensitivity approach (hereafter ICFS). Even though this methodology is, by far, the most commonly employed, it has been seriously challenged both at empirical and theoretical levels (e.g. Alti, 2003; Coad, 2010; Kaplan and Zingales, 1997; see also Carreira and Silva, 2010, for a survey).

Ever since, the empirical literature has strived to find consistent methodologies to measure constraints. Examples of these measures can be found in Almeida et al. (2004), who suggest the use of cash to cash-flow sensitivities, the Euler equation approach proposed by Whited (1992), different composite indexes such as those advanced by Lamont et al. (2001), Whited and Wu (2006) or Musso and Schiavo (2008) and, recently, firm-level cash-flow sensitivities in line with Hovakimien and Hovakimien (2009)—not to mention the use of proxies and, when available, credit ratings (e.g. Bottazzi et al., 2008)

Nevertheless, there are a number of advantages and disadvantages of using each measure (see Silva and Carreira, 2012b, for an overview). In fact, due to the nature of financial constraints—firm-specific, time-varying, and not a clear-cut dichotomous phenomenon (Musso and Schiavo, 2008)—, finding an objective and consistent measure of constraints may prove to be a serious challenge. As pointed by Coad (2010), using rather fragile methodologies (on either empirical or theoretical grounds) to derive strong policy conclusions is not uncommon among the empirical literature of this field. Accordingly, in this paper we make use of three different approaches in order to obtain robust results and ultimately draw relevant policy implications: *a*) self-assessed measure; *b*) MS index; *c*) HH index.

2.2. Subsidies to innovation

There are several arguments behind policy actions in the form of public financial support to firms.[2] Among these, the role of subsidies to innovation and those aimed at stimulating R&D spending, has been given particular emphasis in the last few years (e.g. Aerts and Schmidt, 2008; Almus and Czarnitzki, 2003; Bloom et al., 2002; Schneider and Veugelers, 2010).

The main theoretical arguments for public financial support of innovation efforts and R&D spending (hereafter subsidies for simplicity) can be summarized in: *a*) the "public good" nature of knowledge—higher social than private returns to R&D investment, due to incomplete appropriability and knowledge spillovers; *b*) the "financial market failure"—R&D investments are riskier, harder to use as collateral and entail significant information asymmetry problems leading to financial constraints (see Hall and Lerner, 2010, for an overview).

The common departing point is the well known importance of innovation as a key driver of economic growth. Within this literature, we identify two different, but closely related lines of research. On the one hand, there is a large body of literature that stresses the importance of financial constraints as a barrier to R&D investment and innovation (e.g. Czarnitzki and Hottenrott, 2011; Savignac, 2008; Silva and Carreira, 2012a). On the other hand, research has recently focused on whether innovation subsidies crowd out, or stimulate private R&D investment (David et al., 2000). Even though subsidies appear to have a crowding-out effect when it comes to development activities (Clausen, 2009), state of the art literature suggests that innovation subsidies do have an additionality effect upon R&D expenditure (e.g. Aerts and Schmidt, 2008; Czarnitzki and Bento, 2011)—particularly with respect to research activities, that are usually found to be more affected by financial constraints (Czarnitzki et al., 2011). The existence of common points between these two lines of research seems worthwhile exploring.

[2] Within a policy perspective, it seems worthwhile mentioning the increased interest, within the European Union, to address the financing problems SMEs. Examples can be found in. the recent package of almost €1 billion to finance such firms—European Commission press release IP/11/900 under the FP7 policy—, or the recent ECB efforts to unveil the extent to which firms are financially constrained—*Survey on the access to finance of SMEs in the euro area (SAFE).*

2.3. Main Hypotheses

The question that we tackle in this paper is however slightly different. Rather than analysing the effect of either financial constraints or subsidies on R&D spending and innovation activity, we focus on whether subsidies are allocated to financially constrained firms and if they effectively reduce such constraints.

Since financial resources are not unlimited, notoriously in the present days, choosing where to allocate public funding is crucial. Accordingly, suppose that there are two firms that only differ in their ability to raise external funds. While one is financially constrained the other is not. Additionally, let us assume that scarce public resources force the policymaker to finance only one firm.

On the one hand, the role of lack of external finance as a barrier to innovate is well documented in the literature. On the other hand, recent empirical evidence suggests that subsidies have an additionality effect upon R&D expenditures and increase the probability to innovate (Section 2.2). If we employ the usual argument for public financial support of innovation based on the latter findings, funding will be channelled to that firm that is expected to have a higher probability to innovate.

However, suppose that both face the same technological opportunity but, due to information asymmetry problems, the unconstrained firm is a subsidy recipient, while the constrained one is not. Evidently, the latter will not be able to innovate. What if the policymaker choses to finance the constrained firm, instead of the unconstrained one? In this situation, both will be able to innovate. The reason lies on the very fact that without public funding the constrained firm will never innovate, while the unconstrained firm is always able to obtain external funding (by definition).

In fact, it seems sensible to argue that, within firms that want to innovate, public funding should be aimed at those that otherwise would not be able to finance such innovations (financially constrained firms). Accordingly, one should expect that the probability of a firm receiving subsidies should undoubtedly depend on its level of financial constraints. If that is not the case, then this form of public financial support may not be that different from the usual sources of private external finance. This discussion leads us to formulate the following hypothesis:

Hypothesis 1. Subsidies are allocated to financially constrained firms.

Furthermore, it is apparent that subsidies directly increase firms' financial capacity in the short term. However, when it comes to information asymmetries and firms' access to external funds, as well as long term financing ability, the effect is not as clear. It is now time to ask ourselves whether subsidies play a role in reducing information asymmetries, therefore enabling firms to obtain external finance in subsequent periods. In other words, should subsidies work as a quality stamp, or do they suggest to investors that recipients are not viable?

On the one hand, if public funding enables firms to engage in patenting activity (Audretsch et al 2012), increases firms' economic prospects and if it signals quality to private investors (Kleer, 2010), subsidies may well reduce financial constraints in the long term (Meuleman and De Maeseneire, 2012). On the other hand, such subsidies may lead to a relative inertia of firms—that may eventually become subsidy dependent, illustrated by "subsidy persistence" found in the literature (e.g. Hussinger, 2008)—without necessarily improving firms' ability to raise private external funds. Accordingly, it is the aim of this paper to test whether:

Hypothesis 2. Subsidies reduce firms' financial constraints.

3. Data and Methodology

3.1. Data

We construct a unique dataset from the combination of the three different data sources provided by the Portuguese national Statistical Office (INE)—*Ficheiro de Unidades Estatísticas* (FUE), *Inquérito às Empresas Harmonizado* (IEH) and *Community Innovation Survey* (CIS). As a result, we are able to construct a panel comprising variables on firms' financial status (IEH) and generic characteristics (FUE), further enriching the innovation information on CISs surveyed firms. Accordingly, our final dataset is composed by three CIS waves, corresponding to the years 1997, 2000 and 2004 (CIS 2, 3 and 4, respectively), comprising 8,132 observations. This information is appended by an unbalanced panel (FUE and IEH) of the respective 7,079 firms for the period 1996-2004, resulting in 30,177 observations available (see Table A1, Appendix).

The use of CIS is crucial to the analysis of public financial support to firms' innovation activity. Among other variables, it contains valuable information on innovation, R&D expenses, subsidies to innovation and, remarkably, a direct measure of

financial constraints to innovate—see the Appendix for a detailed description of the variables used.

3.2. Measures of financial constraints

Due to the problems associated with measuring financial constraints, we make use of different methodologies to analyse the nexus between innovation subsidies and firms' constraints. First, we construct a direct measure from the information on firms' perception of constraints—available in the CIS survey. Second, we employ the approach suggested by Hovakimien and Hovakimien (2009), hereafter HH index. Finally, we resort to the methodology proposed by Musso and Schiavo (2008), hereafter MS index.

3.2.1. Direct measure

The first measure employed to assess firms' financial constraints results from a survey question regarding the extent to which firms perceive that the lack of external finance significantly hampered their innovation activity (see the Appendix B for further detail). The use of firms' self-evaluation of financial constraints has a number of advantages and disadvantages that we summarize as follows.

The main advantage of using this measure results from the fact that firms are the best informed agents with respect to the quality of their investment projects. Therefore one should expect that investment opportunities (a crucial problem in typical measures of constraints) are already taken into account in firms' responses.[3] However, the subjective nature of the self-assessed variable means that potential biases, resulting from individuals' perception, may exist. As an example, we might have respondents that feel that their firm is highly financially constrained, when it actually is much less constrained than another firm reporting a low level of constraints.[4] Furthermore, it is worthwhile noticing that the qualitative nature of the underlying question results in an ordinal variable, which requires the appropriate non-linear estimation techniques.

[3] Note that deliberate missreporting should not be an issue since the data obtained from these surveys is confidential.

[4] Some studies overcome this problem by using data on the credit requested and effectively granted (e.g. Meuleman and De Maeseneire, 2012; Russo and Rossi, 2001), however we do not have access to such information.

Even though we do not have information on subsidy amounts, we are able to extract (from the CIS surveys) a binary variable that indicates whether or not a firm received subsidies to innovation. It also seems worthwhile mentioning that this variable results from a much more objective underlying question than, for example, the survey's question on firms' self-assessed financial constraints. While in the former firms are asked if they have received public funding, the latter requires that firms reveal their perception on how difficult it is to obtain external finance—carries a significant amount of subjectivity.

3.2.2. HH index

Alternatively, we also resort to the HH index that avoids the subjectivity and non-linearity problems of our direct measure. This index is an indirect measure that picks the firm-specific relationship between investment and cash-flow, in the light of the well known approach based on ICFS, originally proposed by Fazzari et al. (1988).

The HH index compares the time average of investment weighted by cash-flow, against the simple time-average of investment. Accordingly, investment receives a higher weight in years when cash-flow is higher, capturing the sensitivity of investment with respect to variations of cash-flow. Therefore, if a firm invests more (less) in years with higher cash flow, the HH index will yield positive (negative) values. The reverse is also true. The index is constructed in the following way:

$$HH\_I_i = \sum_{t=1}^{n}\left[\frac{(CF/K)_{it}}{\sum_{t=1}^{n}(CF/K)_{it}} * \left(\frac{I}{K}\right)_{it}\right] - \frac{1}{n}\sum_{t=1}^{n}\left(\frac{I}{K}\right)_{it}, \quad (1)$$

where CF is cash-flow, I is investment, K is total assets, n the number of annual (t) observations for firm i. However, in order to avoid extreme negative values, all cash-flow observations with negative values are set to zero.[5]

Even though this measure captures firm-level heterogeneity of financial constraints, these are assumed to be constant over time. Therefore, this approach does not account for the possibility that the same firm faces different states of constraints along the timeline (see Cleary, 1999; Hubbard, 1998). Additionally, this methodology

[5] This is the same procedure as in Hovakimien and Hovakimien (2009).We also remove firms for which investment level is only observed once.

fails to control for investment opportunities and other variables affecting investment, as well as it does not explore marginal effects (see D'Espallier et al., 2009, for a critique).[6] Finally, it assumes that ICFS correctly identifies firms' financial constraints.

3.2.3. MS index

As we have pointed out in Section 2.1, a good measure of financial constraints should accommodate the fact that these are both firm-specific and time-varying. In this line, Musso and Schiavo (2008) propose an index that allows for individual and temporal heterogeneity of constraints. The strategy is to rank firms (according to proxies of financial constraints) in a certain class (e.g. industry) that is believed to be reasonably homogeneous. Therefore, one can build a score of constraints based on the relative rankings of a given number of variables for a certain firm, within a certain class. The motivation for using homogeneous classes is to account for specificities that may affect the relationship of the proxies and the genuine level of constraints. As a result, for a given firm, higher values of the MS index will reflect a higher level of constraints relative to the class mean.

The procedure takes two steps. First, we identify a number of proxies of financial constraints.[7] Second, for each of these variables, we compute the relative position (rank) of each firm to the corresponding industry mean. As an example, if a firm is very old and large relative to the industry mean, it is considered not to be constrained. If the reverse it's true, then such firm is assigned as constrained. Third, to allow for different degrees of constraints, we build intermediate levels based on the individual rankings—we create five distinct levels according to the quintiles of the relative distribution of each proxy. Finally, we collapse the rankings from all the proxies into a single score of financial constraints for each firm-year.[8]

[6] The tests based on Fazzari et al. (1998) rely on the on the assumption that, holding investment opportunities constant, investment responds positively to cash-flow if a firms is financially constrained (no sensitivity should be found for unconstrained firms).

[7] The index is constructed based on the following variables: size (total assets), profitability, liquidity (current asset over current liabilities), cash flow generating ability (the maximum amount of resources that a firm can devote to self-financing), solvency (own funds over total liabilities), trade credit over total assets, repaying ability (financial debt over cash flow). To avoid extreme values, all variables are winsorized at the 1% level.

[8] We collapsed the different variable rankings by summing them over each firm (obtain a score) and then are rescale the index to 1-10, using the deciles of the score distribution.

We should note however that there are two major drawbacks when using this approach. First, if there are non-linearities in the relationship between the proxy and the effective level of constraints, the final score will misrepresent the level of constraints. In this situation, nothing guarantees that the difference between a firm scoring 1 and 2 is the same as the difference between the levels 2 and 3. As a result, the score of constraints must be analysed as an ordinal variable, which has significant implications in the choice of the estimation procedure. Second, the disaggregation in relatively homogeneous classes of firms might entail considerable difficulties when comparing firms across classes. As an example, if the index is built on relative rankings for each industry, and if the less constrained firms in industry A is more constrained than the most constrained firm in industry B, one can not compare the scores of firms in industries A and B because of different benchmarks.[9]

Nevertheless, we are able to overcome these difficulties by using the appropriate non-linear regression techniques, as well as by weighting each firm score by the industry's average level of financial constraints. To obtain industry average levels of financial constraints, we estimate (for each industry) the sensitivity of cash to cash flow, in line with the methodology suggested by Almeida et al. (2004) and the findings in Silva and Carreira (2010).

3.3. Estimation strategy

The analysis of the nexus between innovation subsidies and firms' financial constraints reveals a number of difficulties associated with the non-linear nature of the variables of interest (Table 1), as well as with endogeneity problems.

Even though the usual problem related to survey artificial correlation between variables of interest may not be as serious due to the objectivity of our subsidy variable, there are nevertheless reasons to suspect of endogeneity. Firstly, if a firm is financially constrained, it might be seen as a potentially more appropriate target for public policy, as well as there is a higher probability that it applies for subsidies (we do not have data on subsidy requests). Secondly, endogeneity may be present due to potentially correlated unobservables. Among others, we should refer to public policy goals and

[9] Note that firms operating in some industries are, on average, more constrained than firms in other industries (Silva and Carreira, 2010).

budgets, firms' applications for subsidy programs and the quality of the underlying project (Jaffe, 2002; Schneider and Veugelers, 2010).

Table 1. Variables measuring financial constraints

Measure	**Nature**	**Comments**
Direct	Ordinal	Subjective Firm-specific Varies across waves
HH index	Continuous	Assumes ICFS holds Firm-specifc Time invariant
MS index	Ordinal	Assumes same level of constraints across industries Firm-specific Varies across years
Weighted MS index	Ordinal (assumed continuous)	Firm-specific Varies across years

The combination of non-linear estimation techniques that accommodate binary and either ordinal or continuous variables, as well as possible endogeneity issues, result in the use of distinct estimation techniques, outlined as follows. (We also report the estimation results for the corresponding specifications without controlling for endogeneity.)

Finally, if the existence of financial constraints increases the probability of a firm being subsidy recipient, and if subsidies reduce financial constraints, it seems sensible to make use of the panel structure of our data and introduce lags (balance sheet variables as well as a specification with lagged CIS variables).

3.3.1. The probability of receiving subsidies

While our subsidy variable is dichotomous, both the MS index and direct measure of constraints are of ordinal nature (Table 1). Therefore, in order to investigate the impact of financial constraints upon the probability that a firm receives subsidies, we specify a model of two latent simultaneous equations as follows:

$$\begin{cases} SUB^{*} = X_1\beta_1 + \alpha_1 FC + \varepsilon_1 \\ FC^{C*} = X_2\beta_2 + \alpha_2 SUB + \varepsilon_2 \end{cases}. \quad (2)$$

For logical consistency purposes we set ($\alpha_2 = 0$) and additionally normalize the variance of the errors:

$$\begin{cases} SUB^{*} = X_1\beta_1 + \alpha_1 FC + \varepsilon_1 \\ FC^{C*} = X_2\beta_2 + \varepsilon_2 \end{cases}, \quad \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim \Phi_2 \begin{bmatrix} 0 \\ 0 \end{bmatrix} \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}. \quad (3)$$

where *SUB* is the binary indicator of whether a firm received subsidies, *FC* is a measure of financial constraints, while SUB^{*} and FC^{*} are the corresponding unobserved latent variables.[10]

Additionally, the vector X_1 includes a number of variables that may influence the probability of a firm receiving subsidies: size (*SIZE*), age (*AGE*), percentage of R&D employees (*RD_WORK*), market share (*MKTS*), exports (*EXP*), percentage of foreign capital (*FOR_K*), cooperation with other firms and institutions (*COOP*), share of subsidies by industry (*SUB%I*) and region (*SUB%R*), registry of patents (*PATENT*) and intangibles (*INTANG*).

Furthermore, in the vector X_2 we include the usual determinants of *FC*. This equation explains financial constraints through the combination of both firms' characteristics and financial variables: firm size (*SIZE*); firm age (*AGE*); 2-digit industry dummies (CAE rev 2.1); percentage of public and foreign capital (*PUB_K* and *FOR_K*, respectively); sales growth (ΔY); cash stocks (*CS*); cash-flow (*CF*); leverage (*LEV*); debt and equity issuances (*ISS*); changes in interest paid (ΔINT); returns on financial investments (*R_FinI*); exports (*EXP*); market share (*MKTS*). All these variables are obtained from balance sheets. Therefore, we use the first lag of these variables to account for the CIS wave span and reduce artificial survey correlation. Exceptions are *PUB_K*, *FOR_K*, ΔY, *ISS* and ΔNWC , since they either do not have sufficient annual variation, or their construction is based on the previous period (would imply the loss of all CIS2 observations).[11]

[10] We also test the corresponding probit, where we do not control for the possible endogeneity of financial constraints. In this case the ordinal FC variable is collapsed into a binary indicator. Additionally, we use a specification with the wave lag of financial constraints, even though we have to drop the HH index measure due to lack of time variability by construction (Section 3.1.2).

[11] See the Appendix for further detail on the construction of variables

We further extend the model to allow *FC* outcomes to be ordinal and estimate the corresponding simultaneous equations ordered probit model—see Greene and Hensher, 2010, pp. 222 for details and Sajaia, 2008, for STATA implementation.[12] Finally, if there are no omitted or unobservable variables that affect simultaneously *SUB* and *FC* ($\rho=0$), we can estimate the equations separately.[13]

However, some of the measures of financial constraints are continuous (Table 1). Accordingly we drop the latent variable specification and estimate their impact upon the dichotomous subsidy variable using an instrumental variables extension of a probit regression. The instruments used are those corresponding to variables in the vector X_2. This is the case of the HH index, as well as the MS index weighted by industry cash to cash-flow sensitivity. With respect to the latter, even though it is a weighted ordinal variable, we assume it to be continuous. Eventual non-linearity problems are minor due to an extensively large number of different values and since interest lies in the signal rather than the amplitude of the impact. Formally, we assume that the values of this ordinal variable approximate those of the unobserved latent continuous variable ($FC \approx FC^*$).

3.3.2. The impact of subsidies on financial constraints

In order to analyse the impact of subsidies upon firms' financial constraints (ordinal measures), we use the same estimation approach as in the previous section. Accordingly, we specify a simultaneous equations probit model (with the corresponding latent variables specification), that we further extend to the ordered probit case. The same logical consistency constraint applies and we also normalize the variance of the errors. Therefore, we simultaneously estimate the following model:

$$\begin{cases} FC^* = X_2\beta_1 + \alpha_1 SUB + u_1 \\ SUB^* = X_1\beta_2 + u_2 \end{cases}, \quad \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \sim \Phi_2 \begin{bmatrix} 0 \\ 0 \end{bmatrix} \begin{bmatrix} 1 & \varsigma \\ \varsigma & 1 \end{bmatrix} \tag{4}$$

[12] Note that since the estimation of marginal effects (in this case) is of rather hard computation and above all interpretation we refrain from estimating them. Nevertheless, interest lies in the signal rather than on the magnitude of the effects.

[13] This parameter can be used to test exogeneity.

where the vectors X_1 and X_2 include the same determinants described in the preceding section. Again, if there are no omitted or unobservable variables that affect simultaneously *SUB* and *FC* ($\varsigma = 0$), we can estimate the equations separately.[14]

For the case of continuous financial constraints measures (HH and weighted MS indexes), we specify a simple treatment effects model to estimate the impact of an endogenous binary treatment (*SUB*) on our fully observed dependent variable (FC):

$$FC = X_2\beta_1 + \alpha_1 SUB + v_1, \tag{5}$$

$$\text{with } SUB \begin{cases} 1, \ if \ \ SUB^* = X_1\beta_2 + v_2 > 0 \\ 0, \qquad otherwise \end{cases}, \text{ and } \begin{pmatrix} v_1 \\ v_2 \end{pmatrix} \sim \Phi_2 \begin{bmatrix} 0 \\ 0 \end{bmatrix} \begin{bmatrix} \sigma^2 & \rho\varsigma \\ \rho\varsigma & 1 \end{bmatrix}.$$

The corresponding models, that assume endogeneity away, are also estimated. Namely, we estimate an ordered probit (for ordinal *FC*) and regular OLS (for continuous *FC*).

4. Empirical Results

4.1. Descriptive statistics

4.1.1. The different measures of financial constraints

As it is described in Table 2, there is a remarkable number of firms that face financial constraints. While only 56% of firms report not to be constrained, the HH index is higher than zero for 54% of the observed firms, suggesting the presence of constraints. With respect to the MS and weighted MS indexes, this picture is not as clear because there is no objective threshold distinguishing firms between constrained and unconstrained. Nonetheless, there is a noteworthy number of firms in the higher rankings of the index.

Additionally, Table 2 shows a positive association between the majority of measures of financial constraints (Spearman rank correlation coefficient). Even though the HH index appears not to move in the same direction as other variables, the remaining measures are positively correlated. Nevertheless, the correlation coefficients are rather low, reflecting the distinct methodologies employed.

[14] As previously pointed, this parameter can be used to test exogeneity.

Table 2. Measures of financial constraints

Ordinal Measures			**Continuous Measures**	
FC	Frequency	Percentage	Weighted MS	
0	1,982	55.58	Min	0.046
1	446	12.51	25%	0.318
2	551	15.45	50%	0.418
3	587	16.46	75%	0.568
Total	3,566	100	Max	1.875
			M	0.457
			Σ	0.223
			Observations	3303
MS index			HH index	
1	678	20.51	Min	-6.666
2	444	13.43	25%	-0.001
3	278	8.41	50%	0.000
4	307	9.29	75%	0.001
5	295	8.92	Max	3.415
6	286	8.65	M	-0.005
7	261	7.89	Σ	0.207
8	346	10.47	HH>0	1692
9	266	8.05		(54.4%)
10	145	4.39	Observations	3110
Total	3,306	100		

Spearman correlation coefficients

	FC	MS index	Weighted MS	HH index
FC	1.0000			
MS índex	0.1626*	1.0000		
Weighted MS	0.0736*	0.5663*	1.0000	
HH index	-0.0014	-0.0255	-0.0488	1.0000

Notes: Brief description and Spearman correlation coefficients of the different variables used to measure financial constraints. Correlation coefficients are consistent with Kendall's τ.

4.1.2. Subsidies and the different measures of constraints

As we can see from Table 3, while 44% of firms report financial constraints (16% reporting high levels of constraints), only 12% are subsidised. Of the highly constrained firms, only 14% receive subsidies, whereas of those that report no constraints, 10% still obtains subsidies. Additionally, of firms that reported the absence of constraints, 25% receive subsidies in the subsequent period. Conversely, 20% of subsidised firms in one period continue to report the highest level of constraints in the following period (only 39% reports not to be constrained). These descriptive statistics provide the first hint that our hypotheses 1 and 2 are questionable.

Table 3. Frequencies of FC and SUB: Self-assessed levels of financial constraints

		SUB_w				SUB_w				SUB_{w-1}		
	FC_w	0	1	Total	FC_{w-1}	0	1	Total	FC_w	0	1	Total
Frequency	0	1,781	201	1,982	0	275	94	369	0	214	53	267
SUB %		89.86	10.14	100		74.53	25.47	100		80.15	19.85	100
FC %		56.68	47.41	55.58		65.79	68.61	66.49		48.09	39.26	46.03
Total%		49.94	5.64	55.58		49.55	16.94	66.49		36.90	9.14	46.03
Frequency	1	393	53	446	1	42	9	51	1	56	24	80
SUB %		88.12	11.88	100		82.35	17.65	100		70.00	30.00	100
FC %		12.51	12.50	12.51		10.05	6.57	9.19		12.58	17.78	13.79
Total%		11.02	1.49	12.51		7.57	1.62	9.19		9.66	4.14	13.79
Frequency	2	462	89	551	2	45	11	56	2	73	31	104
SUB %		83.85	16.15	100		80.36	19.64	100		70.19	29.81	100
FC %		14.70	20.99	15.45		10.77	8.03	10.09		16.40	22.96	17.93
Total%		12.96	2.50	15.45		8.11	1.98	10.09		12.59	5.34	17.93
Frequency	3	506	81	587	3	56	23	79	3	102	27	129
SUB %		86.20	13.80	100		70.89	29.11	100		79.07	20.93	100
FC %		16.10	19.10	16.46		13.40	16.79	14.23		22.92	20.00	22.24
Total%		14.19	2.27	16.46		10.09	4.14	14.23		17.59	4.66	22.24
Frequency	Total	3,142	424	3,566	Total	418	137	555	Total	445	135	580
SUB %		88.11	11.89	100		75.32	24.68	100		76.72	23.28	100
FC %		100	100	100		100	100	100		100	100	100
Total%		88.11	11.89	100		75.32	24.68	100		76.72	23.28	100

Notes: Frequencies of financial constraints (rows) and subsidies (columns). SUB % (FC %) are relative frequencies within rows (columns) of each cell. For the ordinal FC variable, higher values correspond to higher reported constraints (zero for absence of constraints). We additionally compare current (w) values of FC and SUB with the corresponding CIS wave lagged values (w-1).

This picture does not change if, instead of a subjective self-assessed variable, we use the MS index to measure financial constraints (Table 4). In fact, while 15% of unconstrained firms (lower MS index rank) are subsidised, only 12% of firms in the highest rank of constraints receive subsidies. Furthermore, of unconstrained firms in one period, 22% received subsidies in the following one. In this line, the fact that none (0%) of those firms found to be highly constrained in the preceding period received any sort of subsidy in the next period comes up as a striking number. When it comes to the effects of subsidies, if we group firms in the three higher ranks of the index (levels 8-10), we find that 24% of previously subsidised firms continue to face severe financial constraints.

With respect to the continuous measures of constraints, we test whether the distribution of such variables for subsidy recipients dominates that of non-recipient ones (Table 5). We find that non-subsidised firms have a higher probability to take on higher values of the weighted MS index with respect to the subsidised firms. In other words, non-recipients are in general more financially constrained. The same is not true when it comes to the HH index. In fact, even if we can not reject the equality of distributions, the negative sign associated with the Fligner-Policello test suggests that, using this measure, subsidised firms are in general more financially constrained.

Finally, we compare the distributions of the main variables of interest for the subsample of firms that do not receive subsidies, against those that do (Table 6). The typical subsidy recipient in our dataset is larger, more export driven, employs a larger share of personnel devoted to R&D, has a larger share of intangible assets, registers patents, cooperates with other private or public institutions and usually belongs to an industry that is more prone to receive subsidies.[15] In terms of industrial activity, subsidies are essentially given to manufacturing firms (73.11%), with a dominant presence of firms in textiles (12.5%), electric, optic and other equipment (11.79%) and chemicals (9.91%).

[15] If we compare the same variables, with respect to their values in the preceding CIS wave, the interpretation of results remains unchanged except for firm exporting behavior. Subsidy recipient firms exported less in the past.

Table 4. Frequencies of FC and SUB: MS index

		SUB_w				SUB_w				SUB_{w-1}		
	FC_w	0	1	Total	FC_{w-1}	0	1	Total	FC_w	0	1	Total
Freq.	1	576	102	678	1	146	40	186	1	124	27	151
SUB %		84.96	15.04	100		78.49	21.51	100		82.12	17.88	100
FC %		20.19	22.52	20.51		34.03	30.08	33.10		26.16	19.29	24.59
Total%		17.42	3.09	20.51		25.98	7.12	33.10		20.20	4.40	24.59
Freq.	2	383	61	444	2	65	21	86	2	55	13	68
SUB %		86.26	13.74	100		75.58	24.42	100		80.88	19.12	100
FC %		13.42	13.47	13.43		15.15	15.79	15.30		11.60	9.29	11.07
Total%		11.58	1.85	13.43		11.57	3.74	15.30		8.96	2.12	11.07
Freq.	3	243	35	278	3	32	22	54	3	47	9	56
SUB %		87.41	12.59	100		59.26	40.74	100		83.93	16.07	100
FC %		8.52	7.73	8.41		7.46	16.54	9.61		9.92	6.43	9.12
Total%		7.35	1.06	8.41		5.69	3.91	9.61		7.65	1.47	9.12
Freq.	4	266	41	307	4	47	12	59	4	42	12	54
SUB %		86.64	13.36	100		79.66	20.34	100		77.78	22.22	100
FC %		9.32	9.05	9.29		10.96	9.02	10.50		8.86	8.57	8.79
Total%		8.05	1.24	9.29		8.36	2.14	10.50		6.84	1.95	8.79
Freq.	5	242	53	295	5	37	12	49	5	48	14	62
SUB %		82.03	17.97	100		75.51	24.49	100		77.42	22.58	100
FC %		8.48	11.70	8.92		8.62	9.02	8.72		10.13	10.00	10.10
Total%		7.32	1.60	8.92		6.58	2.14	8.72		7.82	2.28	10.10
Freq.	6	248	38	286	6	29	11	40	6	41	12	53
SUB %		86.71	13.29	100		72.50	27.50	100		77.36	22.64	100
FC %		8.69	8.39	8.65		6.76	8.27	7.12		8.65	8.57	8.63
Total%		7.50	1.15	8.65		5.16	1.96	7.12		6.68	1.95	8.63
Freq.	7	226	35	261	7	28	5	33	7	28	19	47
SUB %		86.59	13.41	100		84.85	15.15	100		59.57	40.43	100
FC %		7.92	7.73	7.89		6.53	3.76	5.87		5.91	13.57	7.65
Total%		6.84	1.06	7.89		4.98	0.89	5.87		4.56	3.09	7.65
Freq.	8	310	36	346	8	22	10	32	8	27	16	43
SUB %		89.60	10.40	100		68.75	31.25	100		62.79	37.21	100
FC %		10.87	7.95	10.47		5.13	7.52	5.69		5.70	11.43	7.00
Total%		9.38	1.09	10.47		3.91	1.78	5.69		4.40	2.61	7.00
Freq.	9	231	35	266	9	16	0	16	9	40	8	48
SUB %		86.84	13.16	100		100	0.00	100		83.33	16.67	100
FC %		8.10	7.73	8.05		3.73	0.00	2.85		8.44	5.71	7.82
Total%		6.99	1.06	8.05		2.85	0.00	2.85		6.51	1.30	7.82
Freq.	10	128	17	145	10	7	0	7	10	22	10	32
SUB %		88.28	11.72	100		100	0.00	100		68.75	31.25	100
FC %		4.49	3.75	4.39		1.63	0.00	1.25		4.64	7.14	5.21
Total%		3.87	0.51	4.39		1.25	0.00	1.25		3.58	1.63	5.21
Freq.	Tot.	2,853	453	3,306	Tot.	429	133	562	Tot.	474	140	614
SUB %		86.30	13.70	100		76.33	23.67	100		77.20	22.80	100
FC %		100	100	100		100	100	100		100	100	100
Total%		86.30	13.70	100		76.33	23.67	100		77.20	22.80	100

Notes: Frequencies of financial constraints (rows) and subsidies (columns). SUB % (FC %) are relative frequencies within rows (columns) of each cell. For the ordinal FC variable, higher values correspond to higher reported constraints (MS index methodology). We additionally compare current (w) values of FC and SUB with the corresponding CIS wave lagged values (w-1).

Table 5. Comparison of distributions: Weighted MS and HH index

Measures	Kolmogorov-Smirnov (D) (1)	Fligner-Policello (U) (2)
Weighted MS:	0.136	5.605
	(0.000)	(0.000)
HH index	0.045	-0.571
	(0.395)	(0.568)

Notes: We test the equality of distributions of financial constraints between subsidised and non-subsidised firms. The values of Kolmogorov-Smirnov (D) and Fligner–Policello (U) statistics are reported in columns (1) and (2), respectively. The associated P-values are in parentheses. Rejection of the null means that the two distributions are stochastic different.

Table 6. Characteristics of subsidy recipient vs non-recipient firms

	Means and Standard Deviations		Nonparametric tests	
	SUB=0	SUB=1	K-S (D)	F-P (U)
	(1)	(2)	(3)	(4)
SIZE	4.665	5.304	0.227	-10.254
	(1.168)	(1.268)	[0.000]	[0.000]
AGE	3.018	3.105	0.085	-2.530
	(0.716)	(0.746)	[0.007]	[0.011]
FOR_K	0.679	0.764	0.127	-1.870
	(0.826)	(0.751)	[0.000]	[0.062]
RD_WORK	0.133	0.611	0.192	-2.793
	(0.526)	(1.162)	[0.000]	[0.005]
COOP	0.105	0.524	0.418	-6.036
	(0.307)	(0.500)	[0.000]	[0.000]
EXP	0.266	0.361	0.204	-6.026
	(0.512)	(0.516)	[0.000]	[0.000]
SUB%I	0.038	0.166	0.546	-27.287
	(0.067)	(0.161)	[0.000]	[0.000]
SUB%R	38.429	38.786	0.108	0.001
	(44.150)	(38.818)	[0.000]	[0.999]
MKTS	0.120	0.125	0.063	-1.994
	(0.179)	(0.169)	[0.092]	[0.046]
PATENT	0.221	0.481	0.233	-3.610
	(0.558)	(0.670)	[0.000]	[0.000]
INTANG	0.034	0.055	0.257	-11.715
	(0.075)	(0.084)	[0.000]	[0.000]
Observations	3,142	424		

Notes: Comparison of main explanatory variables between recipient and non-recipient firms (columns 1 and 2). Mean values and standard deviations in parenthesis. The values of Kolmogorov-Smirnov (D) and Fligner–Policello (U) statistics are reported in columns (3) and (4), respectively. The associated P-values are in brackets. Rejection of the null means that the two distributions are stochastic different.

Table 7. Subsidy allocation: exogenous financial constraints.

Measure	Direct	MS		HH
Type	FC^c	Original	Weighted	ICFS
	(1)	(2)	(3)	(4)
FC	0.107	0.008	-0.104	0.551**
	(0.083)	(0.015)	(0.180)	(0.236)
SIZE	0.069**	0.085**	0.084**	0.082**
	(0.033)	(0.035)	(0.035)	(0.036)
AGE	0.078	0.054	0.050	0.023
	(0.049)	(0.049)	(0.050)	(0.052)
FOR_K	-0.013	-0.038	-0.046	-0.048
	(0.053)	(0.054)	(0.052)	(0.053)
RD_WORK	0.177***	0.176***	0.174***	0.173***
	(0.048)	(0.047)	(0.047)	(0.048)
COOP	0.969***	0.971***	0.975***	0.980***
	(0.088)	(0.089)	(0.089)	(0.090)
EXP	0.171**	0.182**	0.163**	0.168**
	(0.073)	(0.072)	(0.074)	(0.074)
SUB%I	6.941***	7.125***	7.140***	7.148***
	(0.558)	(0.569)	(0.571)	(0.577)
SUB%R	-0.007***	-0.009***	-0.009***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)
MKTS	-0.906***	-0.998***	-1.015***	-0.887***
	(0.290)	(0.285)	(0.294)	(0.269)
PATENT	0.084	0.098*	0.094*	0.091
	(0.055)	(0.057)	(0.057)	(0.059)
INTANG	0.177	0.327	0.368	0.279
	(0.391)	(0.402)	(0.400)	(0.414)
Observations	3,566	3,306	3,303	3,110
Log-likelihood	-434.8	-425.8	-425.6	-410.3

Notes: Estimates of a probit regression of subsidies on different types of financial constraints: self-assed ordinal variable collapsed into binary (column 1); MS index and industry weighted MS index (columns 2 and 3, respectively); HH index (column 4). Robust standard errors in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

4.2. Subsidy allocation

As we can see in Tables 7 and 8, the extent to which a firm is financially constrained appears to have no impact upon the probability that it receives public financial support. While in Table 7 we report our estimates that do not account for the possibility of financial constraints being endogenously determined, the results in Table 8 explicitly account and test for such possibility. A striking result that is robust to different measures and estimations strategies is the absence of a statistically significant impact (at the 10% level) of financial constraints upon subsidies. The only exception is found with respect to the use of the HH index in an exogeneity scenario (Table 7, column 4), where financial constraints are found to increase the probability of a firm receiving subsidies

(statistically significant at the 5% level). Additionally, when we introduce a time dimension (the CIS waves, Table C1 in Appendix), the extent to which a firm is financially constrained *ex-ante* does not affect the probability that it is subsidy recipient. As a consequence, these results lead to the rejection of our hypothesis 1 that subsidies are being correctly allocated to financially constrained firms. Furthermore, there is no clear evidence suggesting that financial constraints are endogenous since we can not reject that the equations determining subsidies and financial constraints are independent (ρ=0).

Table 8. Subsidy allocation: endogenous financial constraints.

Measure	Direct	MS		HH
Type	FC	Original	Weighted	ICFS
	(1)	(2)	(3)	(4)
FC	0.021	0.082	0.388	3.258
	(0.251)	(0.052)	(1.157)	(3.862)
SIZE	0.062*	0.101***	0.081**	0.078*
	(0.037)	(0.039)	(0.036)	(0.041)
AGE	0.056	0.037	0.050	0.030
	(0.055)	(0.051)	(0.063)	(0.046)
FOR_K	0.178**	0.257***	0.224	0.137
	(0.077)	(0.084)	(0.150)	(0.106)
RD_WORK	-0.008	-0.015	-0.032	-0.054
	(0.055)	(0.055)	(0.056)	(0.046)
COOP	0.167***	0.163***	0.176***	0.136
	(0.049)	(0.048)	(0.052)	(0.100)
EXP	0.987***	0.964***	0.970***	0.814*
	(0.091)	(0.095)	(0.105)	(0.476)
SUB%I	6.795***	6.887***	6.994***	5.904*
	(0.559)	(0.579)	(0.590)	(3.291)
SUB%R	-0.007***	-0.008***	-0.008***	-0.007*
	(0.002)	(0.002)	(0.002)	(0.004)
MKTS	-0.926***	-0.853***	-0.969***	-0.804*
	(0.299)	(0.305)	(0.312)	(0.444)
PATENT	0.075	0.084	0.095	0.059
	(0.058)	(0.059)	(0.065)	(0.072)
INTANG	0.133	0.248	0.219	0.255
	(0.414)	(0.415)	(0.490)	(0.388)
ρ	0.016	-0.225	-0.115	-0.621
	(0.353)	(0.158)	(0.255)	(1.011)
Observations	3,180	3,059	3,056	2,956
Log-likelihood	-2108	-3599	-224.9	-89.80

Notes: Estimates of simultaneous equations specification in line with equation (3) using different measures of financial constraints: self-assed (column 1); MS index and industry weighted MS index (columns 2 and 3, respectively); HH index (column 4). Robust standard errors in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

4.3. Subsidy efficiency

To test whether subsidies reduces firms' financial constraints, we follow the estimation strategy described in Section 3.3.2—in Table 9 we assume that subsidies are exogenous, while in Table 10 we have endogenous subsidies case. Both specifications yield puzzling results. Regardless the measure of financial constraints used, we do not find that subsidies mitigate such constraints. On the contrary, we find a positive and statistically significant impact of subsidies upon the level of constraints. The only exception is found when we measure financial constraints through our weighted MS index. Using this approach, there is no statistically significant impact of subsidies on firms' constraints (Tables 9 and 10, column 3). Furthermore, using a specification with CIS wave lagged effects, there is no evidence that firms that receive subsidies are *ex post* financially constrained (Table C2 in Appendix). These results lead to a clear rejection of our hypothesis 2 that subsidies alleviate financial constraints. Finally, using a specification that accounts for the possible endogeneity of subsidies seems sensible. In fact, except for our weighted MS index, we reject that the equations governing subsidies and financial constraints are independent ($\varsigma \neq 0$).

5. Discussion

The underlying question throughout this paper is whether one should support firms' innovation activity regardless of their ability to obtain external funding. As our findings in Section 4.2 suggest, the extent to which firms are financially constrained is not taken into consideration when allocating public funding—rejection of hypothesis 1. This result is robust to different approaches used to identify and measure constraints. Therefore one might well be subsidising firms that do not necessarily require public funding to undertake their innovation projects, since they are able to obtain external funds privately (by definition of unconstrained firms). Conversely, constrained firms that are not subsidy recipients will hardly be able to innovate since they lack financial resources. The worrying fact is that, as presented in Section 4.1, these firms are not so few.

Table 9. Subsidy efficiency: exogenous subsidies.

Measure	Direct	MS		HH
Type	FC	Original	Weighted	ICFS
	(1)	(2)	(3)	(4)
SUB	0.174**	0.142**	-0.008	0.008*
	(0.074)	(0.068)	(0.016)	(0.005)
SIZE	-0.050**	-0.124***	-0.012**	-0.001
	(0.023)	(0.021)	(0.005)	(0.001)
AGE	0.051	0.029	-0.026***	-0.007
	(0.039)	(0.033)	(0.007)	(0.006)
PUB_K	-0.002	-0.000	0.001***	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
FOR_K	-0.003***	-0.004***	-0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
ΔY	-0.121	0.384***	0.021	-0.010
	(0.102)	(0.093)	(0.018)	(0.011)
CS	-1.018***			
	(0.283)			
CF	-0.662**			
	(0.318)			
LEV	0.226**			-0.103
	(0.108)			(0.072)
ISS	-0.375**	-0.706***	-0.061**	0.034
	(0.170)	(0.137)	(0.027)	(0.043)
ΔINT	12.341***	-3.489	-0.512	1.418
	(3.727)	(3.551)	(0.787)	(0.900)
R_FinI	-11.000	-15.435*	-3.908***	0.045
	(12.050)	(8.392)	(1.143)	(0.321)
EXP	-0.049	-0.317***	-0.118***	0.009
	(0.060)	(0.045)	(0.008)	(0.009)
MKTS	-0.165	-0.568***	-0.095***	-0.001
	(0.101)	(0.091)	(0.021)	(0.008)
Observations	3,208	3,059	3,056	2,956
Log-likelihood\R2	-1701	-3210	0.139	0.030

Notes: Estimates of an ordered probit regression (columns 1-2) and a regular OLS (columns 3-5) of the impact of subsidies on different types of financial constraints: self-assed (column 1); MS index and industry weighted MS index (columns 2 and 3, respectively); HH index (column 4). We deliberately omit variables that are highly correlated with the measure of constraints by construction (columns 2-5). Robust standard errors in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

Table 10. Subsidy efficiency: endogenous subsidies.

Measure	Direct	MS		HH
Type	FC	Original	Weighted	ICFS
	(1)	(2)	(3)	(4)
SUB	0.476***	0.450***	0.004	0.015*
	(0.175)	(0.135)	(0.028)	(0.009)
SIZE	-0.062**	-0.128***	-0.013**	-0.003
	(0.024)	(0.023)	(0.006)	(0.002)
AGE	0.048	0.045	-0.026***	-0.008
	(0.039)	(0.034)	(0.007)	(0.008)
PUB_K	-0.002	-0.002	0.001***	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
FOR_K	-0.003***	-0.005***	-0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
ΔY	-0.115	0.392***	0.021	-0.014
	(0.102)	(0.093)	(0.018)	(0.010)
CS	-1.005***			
	(0.283)			
CF	-0.639**			
	(0.317)			
LEV	0.226**			-0.096
	(0.107)			(0.066)
ISS	-0.356**	-0.720***	-0.061**	0.035
	(0.169)	(0.139)	(0.027)	(0.044)
ΔINT	12.542***	-4.359	-0.513	1.431
	(3.717)	(3.548)	(0.786)	(0.907)
R_FinI	-10.751	-15.537*	-3.885***	0.222
	(11.981)	(8.386)	(1.142)	(0.342)
EXP	-0.056	-0.307***	-0.118***	-0.003
	(0.060)	(0.051)	(0.008)	(0.003)
MKTS	-0.179*	-0.604***	-0.096***	0.004
	(0.101)	(0.094)	(0.021)	(0.007)
ϱ	-0.227*	-0.251***	-0.041	-0.031*
	(0.119)	(0.090)	(0.076)	(0.016)
Observations	3,180	3,059	3,056	2,956
Log-likelihood	-2105	-3596	-273.7	-98.13

Notes: Estimates of simultaneous equations specification (columns 1-2) and treatment effects (columns 3-5), in line with equations (4) and (5), respectively. We use different measures of financial constraints: self-assed (column 1); MS index and industry weighted MS index (columns 2 and 3, respectively); HH index (column 4). We deliberately omit variables that are highly correlated with the measure of constraints by construction (columns 2-5). Robust standard errors in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

There are important variables explaining the allocation of subsidies (e.g. size; exports) that are not different from what private investors\lenders take into consideration when deciding to provide credit. These results may be associated with a necessity of public decision makers to show good results of their policies. If this is the case, then they will opt for "safer" firms—i.e. those that have a higher probability to survive, regardless of the subsidy. However, in such situation, some forms of public financial support (notoriously subsidies), may not be that different from the usual sources of private external finance.

Additionally, as we show in Section 4.3 and contrary to recent evidence (e.g. Meuleman and De Maeseneire, 2012), subsidies might not even reduce financial constraints—rejection of hypothesis 2. Our results point towards a certain accommodation of subsidy recipient firms, driving a subsidy persistence problem with no obvious impact upon the level of constraints. In fact, it is clear that subsidies do not mitigate financial constraints. On the contrary, constraints appear to be amplified if a firm receives subsidies. This finding suggests that subsides possibly drive the pressure from selection forces away, leading to a relative inertia of subsidised firms.

The persistence of public funding, that does neither reduces financial constraints nor is systematically allocated to unconstrained firms, hints at a possible system failure: recipient firms have no incentives to move from public to private funding. It might be the case that subsidies have an additionality effect upon R&D investment (not tested in this paper). However, the persistence of policy actions that disregard firms' financial constraints may crowd out private finance for R&D and innovation activity in the event that financially unconstrained firms dominate the "market for public funds", drying up resources that should be available for constrained firms. The main research question is then whether the incremental innovation output of the unconstrained firm is larger than the innovation output of the constrained one. Even though such analysis is beyond the scope of this paper, it certainly deserves our attention in the future.

Furthermore, our results point towards one of two possibilities. Either public agencies are not able to screen financially constrained firms, or there are serious governance problems that should be dealt with. Therefore, research that analyses the detailed subsidy attribution processes is welcomed. Nevertheless, even if these

problems in the attribution of subsidies are to be mitigated, our paper shows that this policy instrument might prove inadequate to deal with financial constraints.

Our analysis is subject to a number of limitations that we briefly address. First, our research could be improved if we had information *a*) on the specific policy instruments (criteria and amounts) and *b*) on the set of firms that were effectively interested and applied for the public financial support.

Second, our results on the efficiency of subsidies could reflect the fact that *a priori* there is an incorrect allocation of funds. In other words, if unconstrained firms are to receive funding, it is not expected that their levels of constraints would diminish. Still, while in Section 4.1 we show that a significant number of previously constrained (and subsidy recipient) firms continue to face high levels of constraints, our estimates from Section 4.3 show that, if significant, the impact of subsidies on constraints would be positive.

Third, we made a considerable effort, by means of using distinct approaches, to rule out biased conclusions due to incorrect measurement of financial constraints. Notwithstanding, any currently available measure of constraints may well entail a non-negligible amount of error.

Overall, in this paper we provide robust evidence that allows us to conclude that, when it comes to public funding, innovation policy should definitely take into account the ability of firms to raise external funds.

6. Conclusion

In this paper we analyse the nexus between firm's financial constraints and subsidies to innovation. For this purpose we employ different estimation strategies using distinct measures of financial constraints.

Even though innovation subsidies are generally regarded as having an additionality effect upon R&D investment and a positive impact upon innovation, we raise serious doubts on their role in alleviating firms' financial constraints. In particular, our results suggest that while on the one hand subsidies are not being correctly allocated to those firms more affected by financial constraints, on the other hand, these subsidies do not alleviate these constraints.

Finally, our findings have serious implications for future policymaking. Public financial support in the form of subsidies does not seem to be particularly effective in reducing firms' financial constraints. Accordingly, rethinking the subsidy attribution process and\or redirecting public resources to other strategies to alleviate financial constraints to innovate should be given due consideration.

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Appendix

A. Data sources

Table A1. Data sources

Source	Unit	Periodicity	Time span	Target population	Sampling scheme	Information
FUE	Firm	Annually	1996-2004	Portuguese firms	Population	Firm characteristics
IEH	Firm	Annually	1996-2004	Portuguese firms	<100 employees: Stratified by location (NUTS II), industry (CAE rev 2.1) and firm size (employment). >99 employees: Population	Balance sheets
CIS	Firm	Waves: 1997 (II) 2000 (III) 2004 (IV)	Wave span: 1996-1997 1998-2000 2002-2004	Portuguese firms	<250 employees: Stratified by location (NUTS II), industry (CAE rev 2.1) and firm size (employment). >249 employees: Population	Innovation activity

Notes: The data is representative at the regional, sectoral and industrial levels, of the Portuguese economy.

B. Data

From the data at our disposal we were able to create the following variables:

B1. Generic information (FUE)

Age (AGE)	Computed as the difference between the current year and the year of establishment of the firm plus one, in logs;
Industry (CAE)	Portuguese industrial classification—using CAE rev 2.1 as reference. Different industry codes are converted into dummy indicators;
Location (NUT)	European regional classification. Different region codes are converted into dummy indicators;
Public capital (PUB_K)	Percentage of capital owned by the public sector;
Foreign capital (FOR_K)	Percentage of capital owned by non-nationals;

B2. Balance sheets variables (IEH)

Size (SIZE)	Measured as log of the number of employees;
Investment (I)	Measured as additions to plant, property and equipment- gross investment, scaled by total assets;
Cash- flow (CF)	Computed as net income before taxes plus depreciation, scaled by total assets;
Cash stock (CS)	Measured as total cash holdings, scaled by total assets;
Sales Growth (ΔY)	Measured as changes in total sales from previous period;
Debt and equity issuances (ISS)	Sum of debt and equity issuances, scaled by total assets. For the year 2001 equity issuances are reported as missing. The reason lies in legal changes that took place with the introduction of Euro (most firms adjusted their equity, not necessarily meaning issuing equity);
Non-cash net working capital (NWK)	Difference between non-cash current assets and current liabilities, scaled by total assets;
Interest payments (INT)	Interest payments of a firm, scaled by total assets. It can be argued to proxy for the credit rating of the firms;
Leverage (LEV)	Measured as the ration of liabilities to the total value of a firm;
Returns on financial investments (R_FinI)	Returns on financial investments of firms, scaled by assets;
Intangible assets (INTANG)	Computed as intangible assets, scaled by total assets. In the absence of a better alternative, this variable is intended to proxy the knowledge stock, through R&D stock and the patent stock of firms (we do not have detailed information neither on patents, nor on highly disaggregated firm accounts);
Exports (EXP)	Firm exports, scaled by assets;
Market share (MKTS)	This variable is constructed as a firm's sales over total sales of the corresponding firm's industry—at maximum level of industrial classification disaggregation (5-digit).

B3. Innovation variables (CIS)

Public Finance (SUB)	Binary variable for firms that received public funding and those that did not. It includes financial support to innovation activities provided by the Portuguese local or central administration, as well as by the EU (through the "Framework Programs"). This support may take the form of subsidies *strictu sensu*, credit guarantees and tax benefits (from the CIS survey we are not able to distinguish them). For the sake of this paper and simplicity we will refer it as "subsidies";
Share of subsidized firms-Industry (SUB%I)	Computed as the ratio of number of subsidized firms in each industry (2-digit, CAE rev 2.1) to the total number of subsidized firms;
Share of subsidized firms-Region (SUB%R)	Computed as *SUB%I* but for each region (NUT2). Both of these variables serve as instruments for subsidies. The rationale is that, in the absence of information on public policy budgets, the share of subsidies by industry and region will reflect policy goals for certain industries or regions (see Schneider and Veugelers, 2010);
Cooperation (COOP)	Binary variable that indicates if a firms cooperated with other firms or institutions for the purpose of innovation activities;
Patent (PATENT)	Binary indicator of whether a firm registered any patent during the wave period.
R&D workers (RD_WORK)	Percentage of employers in the firm that work on R&D;

All continuous variables of interest were winsorized at the 1% level (0.5% each tail) in order to avoid problems with outliers in the estimation procedures. Deflators used include the Industrial Production Price Index and Labour Cost Index, both drawn from INE, and the GDP deflator, drawn from the Portuguese Central Bank (BdP). Nevertheless, no deflators were used when a variable was constructed as a ratio of two nominal values (normalized). In such cases we assume that the price growth rates are homogeneous.

C. Additional results

Table C1. Subsidy allocation: lagged effect

Measure	Direct	MS	
Type	FC^c	Original	Weighted
	(1)	(2)	(3)
FC_{w-1}	0.182	0.008	-0.657*
	(0.208)	(0.033)	(0.351)
SIZE	0.112	0.121	0.108
	(0.080)	(0.077)	(0.078)
AGE	-0.026	0.060	0.017
	(0.128)	(0.122)	(0.128)
FOR_K	-0.161	-0.121	-0.125
	(0.115)	(0.104)	(0.102)
RD_WORK	0.155	0.130	0.121
	(0.103)	(0.096)	(0.096)
COOP	0.998***	0.988***	1.027***
	(0.202)	(0.189)	(0.190)
EXP	0.156	0.144	0.100
	(0.133)	(0.131)	(0.137)
SUB%I	11.054***	10.415***	10.642***
	(1.785)	(1.402)	(1.456)
SUB%R	-0.011**	-0.010***	-0.011***
	(0.005)	(0.004)	(0.004)
MKTS	-0.662	-1.446**	-1.630**
	(0.603)	(0.684)	(0.710)
PATENT	0.108	0.162	0.166
	(0.132)	(0.119)	(0.120)
INTANG	-0.475	-0.331	-0.331
	(0.930)	(0.802)	(0.810)
Observations	557	616	616
Log-likelihood	-93.31	-106.1	-105.2

Notes: Estimates of a probit regression of subsidies on different types of financial constraints: self-assed ordinal variable collapsed into binary (column 1); MS index and industry weighted MS index (columns 2 and 3, respectively); HH index is dropped because it has no time variability by construction (see Section 3.1.2). Robust standard errors in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

Table C2. Subsidy efficiency: lagged effect

Measure	Direct	MS	
Type	FC	Original	Weighted
	(1)	(2)	(3)
SUB_{w-1}	0.147	0.387***	0.018
	(0.124)	(0.107)	(0.025)
SIZE	-0.000	-0.188***	-0.052***
	(0.053)	(0.056)	(0.013)
AGE	0.006	-0.081	-0.043**
	(0.090)	(0.074)	(0.021)
PUB_K	-0.003	0.004*	0.003***
	(0.002)	(0.003)	(0.001)
FOR_K	0.000	-0.005***	0.000
	(0.002)	(0.001)	(0.000)
ΔY	-0.103	0.066	-0.028
	(0.221)	(0.211)	(0.037)
CS	-2.060***		
	(0.644)		
CF	-0.917		
	(0.689)		
LEV	0.127		
	(0.231)		
ISS	-0.070	-0.281	0.057
	(0.344)	(0.265)	(0.056)
ΔINT	16.229*	3.275	-1.883
	(8.774)	(7.957)	(1.569)
R_FinI	7.021	-10.695	-3.794**
	(22.640)	(13.048)	(1.863)
EXP	-0.234**	-0.227***	-0.064***
	(0.094)	(0.085)	(0.015)
MKTS	-0.052	-0.059	-0.060*
	(0.177)	(0.161)	(0.036)
Observations	556	595	595
Log-likelihood\R2	-383.2	-697.7	0.202

Notes: Estimates of an ordered probit regression (columns 1-2) and a regular OLS (columns 3-5) of the impact of subsidies on different types of financial constraints: self-assed (column 1); MS index and industry weighted MS index (columns 2 and 3, respectively); HH index is dropped because it has no time variability by construction (see Section 3.1.2). We deliberately omit variables that are highly correlated with the measure of constraints by construction (columns 2-5). Robust standard errors in parentheses. ***, **, and * denote statistical significance at the .01, .05, and .10 levels, respectively.

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