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TAX INCENTIVES AND DIRECT SUPPORT FOR R&D: WHAT DO FIRMS USE AND WHY?

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Abstract (*)

The measurement of the effects that public support to private R&D has on R&D investment and output has attracted substantial empirical research in the last decade. The focus of this research has mostly focused on testing for possible crowding out effects. There is virtually no study aiming at understanding how and why these effects may or may not be occurring. In addition, the effects of the two most common tools of public support, direct funding through grants and loans, and tax incentives, have been studied separately.

We contribute to existing work by focusing on the determinants of the use by firms of these two mechanisms and their potential link to sources of market failures. We think this is an important step to assess impact estimates. Using firm-level data from the Spanish Community Innovation Survey (CIS), we find that firms that face financial constraints, as well as newly created firms, are less likely to use R&D tax credits and more likely to apply for and obtain direct public funding. We also find that large firms that care about knowledge protection are more likely to apply for and obtain direct funding, while SMEs are more likely to use tax incentives. Our results show that direct funding and tax credits, as currently designed, are not perfect substitutes because firms are heterogeneous, and suggest that from a social perspective, and provided that crowding out effects can be ruled out for both instruments, some combination of both may be preferable to relying on only one.

Keywords: R&D subsidies, R&D tax credits, R&D, policy evaluation, CIS

JEL Classification: H25, L60, O38, O31

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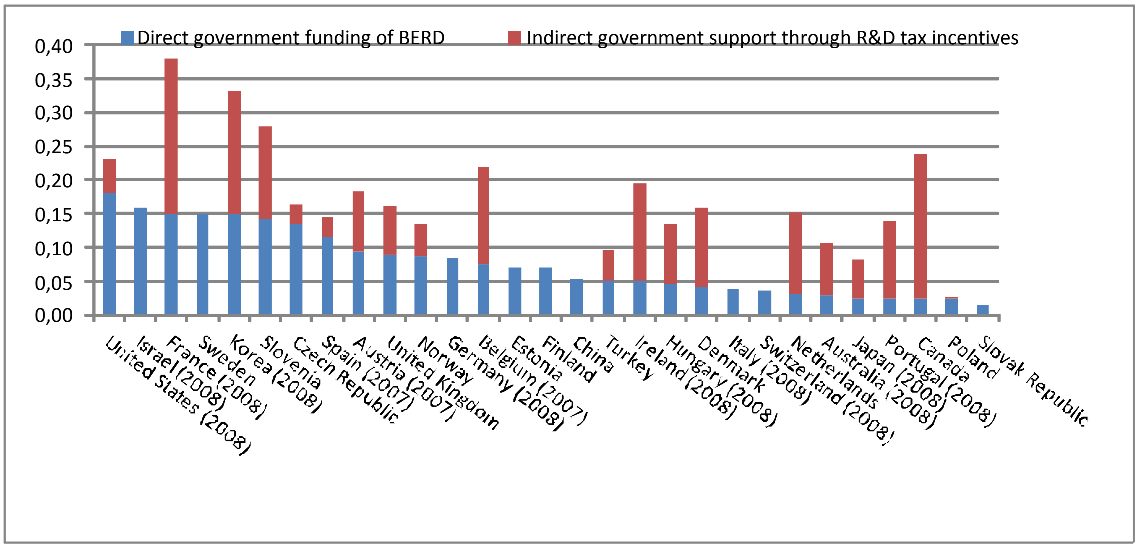
1. INTRODUCTION

Tax incentives and direct funding are two instruments currently used in many countries to stimulate private R&D activity. Both belong to a broader package of measures addressed to enhance private research and innovation activities that includes intellectual property rights, public funding of basic research and public provision of venture capital. While direct public funding of private R&D has a long tradition in many countries, tax incentives have spread gradually, although with some exceptions. Canada, The Netherlands and Japan rely mostly on tax incentives, while direct funding is still preferred Sweden, Finland or Germany. Other countries combine both instruments France, Denmark, Spain and the United States fall in this category. Figure 1, shows OECD estimates of the relative weight of each instrument as a share of GDP in 2009 by country.

Figure 1: Direct funding and Tax Incentives for business R&D 2009
(in % of GDP)



Notes:
Direct funding includes grants, credits and public procurement. Indirect funding refers to all tax incentives related to R&D: tax credits and allowances, social security contributions, reductions in R&D labor taxes. Sub-national tax incentives are not included. Israel, Italy and Slovak Republic proved R&D tax incentives but cost estimates are not available. For detailed information check the source.
Source: OCDE (2011a), OECD Science, Technology and Industry Scoreboard 2011

The common argument for the provision of public incentives to private R&D activities rests on the positive spillovers associated to the production of knowledge. There is by now a large body of empirical evidence showing a gap between estimates of private and social returns to R&D at the firm, industry and country level, providing thus a solid ground for policy measures. A second argument for public support that adds to the first is the undersupply of funding for innovative projects. Technical and market risk, coupled with asymmetric information between the innovator and the financial investor, generate a gap between the cost of capital for these projects and the market cost of capital. Since external finance is more expensive than internal finance, only firms that have sufficient internal finance will undertake some R&D projects.[1]

Which particular form public support should take to correct for these sources of market failure is, however, a matter of debate. Do both instruments in practice address both sources of market failures? Are there situations where one is to be preferred to the other? Or, in other words, is there an "optimal mix" of both instruments? While there is substantial empirical research estimating the effects of each instrument separately on private R&D decisions and outcomes (see for instance Bloom, Griffith and Van Reenen, 2002 and Lokshin and Mohnen, 2011 for evidence on tax credits; and Gelabert, Fosfuri and Tribó, 2009 and Czarnitzki, Ebersberger and Fier, 2007 for direct grants), to the best of our knowledge the explicit comparative analysis embedded in the questions we raise remain virtually unexplored.[2]

This paper contributes a step in this direction by bringing into focus the comparative allocation of tax credits and direct funding. We take the two traditional factors causing market failures in R&D, knowledge spillovers and financial constraints, and assume that if they truly affect firms' decisions, they must be perceived by firms as hurdles to potential innovation plans. We then study whether a relationship exists between these hurdles and the use of each instrument,

[1] Hall and Lerner (2009), who survey the evidence on the funding gap for investment in innovation, conclude that even in the absence of knowledge externalities small and new firms experience high costs of capital; for large firms, however, the evidence is mixed.

[2] The comparative study of policy instruments is an important issue for policy-makers. See the testimony by the OECD for the US Senate Committee on Finance, OECD(2011b).

controlling for a set of factors. This step may provide insights for interpreting the range of results that are obtained in impact evaluation studies.[3]

We use firm-level data from two waves of the Spanish Community Innovation Survey (CIS) to study this question. We find that firms that face financial constraints to undertake innovation projects, as well as newly created firms, are less likely to use R&D tax credits. SMEs that face this type of constraint, however, are more likely to apply and obtain direct public funding. Regarding appropriability concerns, large firms that care about protection are more likely to apply for and obtain direct funding, while SMEs are more likely to use tax incentives. Our main results are robust to changes in the definition of dependent variables and for most subsamples of firms.

These results suggest that direct funding and tax credits are not perfect substitutes. Firms that are financially constrained but have good innovation projects need support to be able to carry them out and obtain profits before being able to claim tax credits. Firms that face small limited appropriability difficulties may find tax incentives more appealing than direct support because the cost of applying for direct funding may be high compared to the chances of obtaining it when innovation is not very drastic. Provided that crowding out effects can be ruled out for both instruments, some combination of both would be preferable from a social point of view to relying on only one.

The paper is organized as follows: in the next section we review a selection of literature related to our research questions. In section 3 we describe the data, variables and empirical model that

[3] To illustrate this point: assume that from firm-level data we obtain that there is no additionality in private R&D expenditure, and that the share of sales of new products is not significantly different from non-supported firms. Should we conclude that the policy is not effective? The answer depends on whether supported activities generate spillovers that are captured by the firms'competitors. Since spillovers are one of the theoretical arguments for providing public support, allocation equations should capture this concern to some extent.

will be used. In section 4 we show and discuss estimation results. Finally section 5 contains concluding remarks.

2. PREVIOUS EVIDENCE AND SOME NEW PROPOSITIONS.

Many theoretically possible policy instruments to address market failures affecting R&D may have drawbacks. Direct public funding through subsidies or grants reduces the private costs of investing in R&D, but places high information requirements for the public agency awarding them. Tax credits and allowances may appear to be a neutral, simple and non-interfering tool, but the specific design is important, as they may be claimed for projects that the firm would have been done anyway. Producing empirical evidence evaluating the impact of both on a set of outcomes becomes very valuable for policy design and improvement. Over the last ten years, a significant volume of empirical research to assess the impact of either direct support or of R&D tax credits on the level of private R&D investment has been developed. The main concern of most of this research has been testing for the presence of full crowding out effects, which would imply a waste of public resources, but the impact on other outcomes such as patents, productivity or sales of new products has also been analyzed.

With only a few exceptions (Haegeland and Moen, 2007, Berubé and Mohnen, 2009 and Marra, 2008), however, the effects of each tool have been studied separately.[4] Tax incentives are usually modelled as part of the user cost of capital in standard investment models, where the estimated R&D price elasticity provides a measure of the impact of tax incentives. Bloom, Griffith and Van Reenen (2002) used country-level data and found an elasticity of about 0.1 in the short run and about 1 in the long run. Firm level studies have followed since, and some cast

[4] Haegeland and Moen (2007) find that the additionality of tax credits is higher than the additionality of grants awarded through the Research Council and Innovation Norway, which would be consistent with the latter selecting projects with large externalities but low private return. Berubé and Mohnen (2009), whose sample of Canadian firms contains firms that benefit from tax credits, a subset of which received subsidies, find that those receiving subsidies introduced more new products and made more world-first product innovations. These authors estimate program participation equations that do not include indicators of financing constraints or of spillovers. Marra (2008) estimates an R&D investment equation and finds that both instruments increase private investment.

a somewhat skeptical view on this type of R&D support, at least for level-based tax incentives. In particular, Lokshin and Mohnen (2011), using a Dutch panel of firm level data, obtain elasticities of 0.4 and 0.8 respectively. They also find that elasticities are larger (in absolute value) for small firms (less than 200 employees) than for large firms. Using these elasticities they estimate that 1 euro of tax receipts foregone generates 3.2 euros of R&D by small firms, 0.78 euros for large firms. For large firms therefore crowding out cannot be rejected.[5] They suggest that small firms may be more sensitive to tax incentives because they are more likely to be credit constrained, but do not test this proposition.

The purpose of this modelling approach is to explain R&D investment as a function of its price, and provides a framework for testing crowding out effects, which is an extremely important issue. But it is not designed to ask which firms are more likely to use tax incentives, and in particular whether incentives allow firms that were not doing R&D to switch to doing R&D. Answers to these questions could offer valuable insights for interpreting estimated elasticities.

A different empirical approach provides a way to test this, although it has not been fully exploited. Rather than using a structural approach, some researchers have used matching methods to obtain an estimate of the impact of tax credits on some outcomes. This method requires controlling for program participation (selection into treatment) in order to be able to compare the outcomes of treated and untreated firms, and involves therefore the estimation of a program participation equation. Even though this is usually done as a purely technical step, results may contain valuable information for policy evaluation if the equation is adequately specified. Corchuelo and Martínez Ros (2008), and Czarnitzki et al (2011) provide two examples of this approach.[6] Corchuelo and Martínez Ros, using Spanish firm-level data, find that small, financially stable firms (those with a ratio of equity over debt higher than 0.5) are

[5] They use the estimated elasticities to run some simulations to calculate the additional R&D investment generated by the tax incentive and the foregone tax income, finding that the government revenue loss is much larger than the increase in private R&D. From this the authors conclude that potential spillovers would have to be very large in order to compensate for the deadweight loss.

[6] See Cappelen et al (2008) for work with Norwegian data, and Duguet (2010) with French firms.

more likely to use tax credits.[7] These results suggest that this type of support is more appealing to small unconstrained firms rather than to constrained firms. Czarnitzki et al use a sample of Canadian firms and include the price-cost margin as an indicator of the firm's internal funding capacity in a probit model of the probability that a firm will use R&D tax credits. They find a positive relationship, although it is not evident how to interpret this result in terms of financial constraints, partly because in their sample there were firms that had also received R&D grants and they all claimed tax credits. Appropriability indicators as a potential determinant of the use of public support are not considered in all this work.

Research on the impact of direct funding (grants and loans) is extensive and shall not be thoroughly reviewed here. The main point of interest for our purposes is that regardless of the modelling approach (whether structural or non-structural methods), some program participation equation is estimated. As before, this is usually taken as a purely technical step to proceed to matching treated and non treated firms. Generally, firm size, industry dummies, and other firm characteristics are typically included in the equation, but no link is made to indicators of market failures. In some cases, an indicator of the firm's financial situation is included among the control variables. Hussinger (2008), for example, uses a credit rating index, and finds that firms with better rating are more likely to obtain direct public funding in Germany. Czarnitzki et al (2007) use an indicator of appropriability, but do not include indicators for funding constraints.

Possibly the work closest to ours in the interest for linking impact evaluation to the presumed market failures is Gelabert, Fosfuri and Tribó (2009), who find evidence that the degree of appropriability matters in explaining the magnitude of the effect that direct public support has on privately financed internal R&D. Although their focus is on the estimation of the additional private R&D investment generated by public support, they estimate a program participation equation where indicators of appropriability and financial constraints are included. Only the

[7] Corchuelo and Martínez Ros also include the lagged B-index in the separate equations for small and large firms, finding that it affects the use of tax credits by large firms, but not by SMEs.

latter is found to be significant, although with a negative sign: contrary to expected, firms with more financial constraints are less likely to obtain direct support. The authors, however, do not explicitly address the link between indicators of market failures and the comparative use of the two forms of support, direct subsidies and tax incentives.[8]

Our work, therefore, adds to the existing body of research by explicitly seeking to test whether there is a correlation between the two potential sources of underinvestment in R&D and the actual use of direct support and tax incentives. The different nature of both tools in some relevant dimensions, and the different degree of public involvement associated to each, set the stage for anticipating heterogeneous effects both across tools and across firms.

A focus on the allocation and use of two types of R&D support.

Some differences in the design of direct funding and tax incentives may have an impact on who benefits from each as well as on some outcomes. Direct public funding is obtained by a firm only if the firm presents an application to the public agency and the public agency decides favourably after screening the proposals. The requirements explicitly and publicly set by the public agency are usually related to the innovative content of the proposal, the technical ability of the firm to carry it out, and the potential market.[9] The agency may have additional preferences for some industries or type of innovation project: it may consider, for instance the expected spillovers generated by the project, or the extent of financing constraints faced by the firm, but these do not seem to be made explicit in national-level programs. The firm runs the project once funding has been approved. Funded projects will reflect both firm and agency preferences: firms will be interested in projects that are profitable after taking into account public support, but by determining the size of this support the agency may select projects that have social value but low private value. There are two drawbacks: 1) applying for direct support has a cost for the firms since preparing a proposal takes time and resources that have an

[8] Gonzalez, Jaumandreu and Pazo (2005) provide an excellent analysis of subsidy effectiveness, but do not study the role of appropriability and financing constraints.

[9] See Huergo and Trenado (2008).

opportunity cost which may not be small for SMEs, and 2) screening for appropriate projects has a cost for the public agency as well.

Tax credits, on the other hand, do not require the presentation and approval of a specific project. A firm may claim a tax credit on any expense that qualifies as a research and development expenditure according to the tax code. The only requirement usually is for the firm to follow proper accounting rules for this type of expenses. A firm will obviously tend to select R&D projects that have a high private profitability. Claiming the credit is relatively easy if the firm fulfills these conditions, because it does so when filing for the corporate tax in period t+1. To be able to benefit from a tax credit, however, the firm must have positive taxable income. Although possibly less costly for firms, this mechanism involves some monitoring costs for the tax authorities. In addition, nothing guarantees that the size of the tax credit will be related to the equivalent optimal subsidy if spillovers are an important issue.

A potentially important difference between both tools is that, in the case of tax credits, the firm must be able to privately fund the project ex-ante, and expect to have taxable income during the same period or within a reasonable horizon. New and small firms may hence be at a disadvantage to benefit from this instrument. An additional difference is that tax credits may be pro-cyclical, in contrast to direct support.

There is virtually no theoretical model of firms' and agency behaviour regading R&D subsidies. Two exceptions are Takalo and Tanayama (2010) and Takalo, Tanayama and Toivanen (2011), who focus on direct support. The first is a theoretical paper linking firms facing constraints to finance their R&D projects, some of which are high quality and others are low quality, and subsidy allocation. The model predicts that firms with high quality projects will always apply for funding, and that subsidies will increase private effort through two effects: 1) by reducing the amount of market based capital, they reduce its cost, and 2) the subsidy becomes a signal of quality for private external funds, which again then reduces their cost.[10] In the corporate taxation literature, Keuschnigg and Ribi (2010) discuss how business taxation may affect financially constrained innovative firms, and find that R&D tax credits encourage innovation but also relax finance constraints and help innovative firms to exploit investment opportunities to a larger extent.

The description of these differences between R&D tax credits and direct support and the theoretical analysis of Takalo and Tanayama and of Keuschnigg and Ribi suggest some intuitive propositions regarding the observed use of each mechanism. The core propositions we want to test are the following:

1. Tax incentives can be considered to be a prize after the investment; they will therefore be more attractive for firms without severe internal or external financing constraints.
2. Direct public funding will be preferred by firms that face financial constraints because this tool provides ex-ante co-financing of projects and, in addition, may allow the firm to rise more private funding after being awarded a grant or loan.
3. Firms with projects facing substantial appropriability problems will prefer direct funding rather than tax incentives. When projects produce quickly imitable innovations, the firm may not expect they will produce a significant stream of profits, nor, consequently, a significant tax credit.
4. Firms engaging in projects with small appropriability problems will prefer tax incentives to direct funding, especially if the cost of applying for direct funding is relatively high relative to the expected grant, and the expected probability of being awarded a grant is small.

[10] Takalo et al (2011) model the subsidy allocation process as a game of incomplete information; their main purpose is to estimate the expected return on subsidies for the agency.

5. New or young firms that intend to innovate are more likely to apply for and obtain direct support than use tax incentives, because they usually are more affected by financial constraints or have little taxable income.

There are obviously other factors that may affect a firm's decision to apply for or use public support for R&D. These include all those shaping the incentives to innovate and/ or perform R&D, such as market structure. In particular, in industries with an established dominant firm the incentives for rival's R&D may be reduced (Cabral and Polak, 2007). Competitive pressure, vertical integration, sunk entry costs and market size may also affect the profitability of engaging in product or process innovations (Aghion et al., 2005 and 2009; Artés, 2009). Some of these factors may be partially taken into account in our empirical analysis. We now turn to the description of the most relevant features of our data.

3. EMPIRICAL DESIGN: DATA, VARIABLES AND ECONOMETRIC APPROACH

3.1. The DATA

The PITEC is a firm-level panel data set developed by the Spanish Statistical Office (INE) based on the Community Innovation Survey, which in Spain is conducted annually. This data base collects information related to innovation activities by firms with more than 10 employees from all manufacturing and service industries. Spanish firms have a legal obligation to respond to questionnaires submitted by INE, and the response rate is high (around 90%).The sample is highly representative of large firms (those with 200 or more employees). It also contains a large number of firms with less than 200 employees, but in this case the sample is biased towards innovators. [11]

[11] This is so because all firms that have received any form of public support for R&D or those that have reported R&D expenses in the current or past years are surveyed every year. The remaining surveyed firms come from a random sample stratified by size and sector among non-R&D performing firms

We use data from the surveys conducted yearly from 2005 to 2008. It is important to note that some questions refer to a three year period (2003-2005; 2004-2006; and so on) and some to the year previous to the survey. Examples of the first type of information are geographical market of the firm, introduction of new products and/or processes, information sources, cooperation to innovate, barriers to innovation, use of public support to innovate and use of intellectual property. Examples of the second type are the number of employees, sales volume, exports, innovation expenditures by category (in-house R&D and others), and sources of funding for in-house R&D. A distinctive characteristic of this survey is the availability of qualitative information on barriers to innovation as perceived by the firm, as well as on the importance of several sources of information for the firm's innovation process.[12].

Tables 1 and 2 describe some features of the sample related to public support for business R&D. Because of the different population representativity, we distinguish along the whole empirical analysis between SMEs and large firms. The last two columns in Table 1 provide information on the extent of the bias towards innovative firms in our sample relative to a representative data source for manufacturing firms frequently used in empirical work, the ESEE. The table shows that for large firms both data sources are very similar in terms of the share of firms that invest in R&D or use R&D support. In the case of SMEs, about 50% of firms in the PITEC sample invest in R&D against 24% in the ESEE sample. SMEs using public support are also overrepresented in PITEC. However, an important advantage of PITEC relative to ESEE is the larger sample size, a feature which becomes important for estimation purposes.[13] Table 1 also shows that, according to both data sources, the use of tax credits is more widespread than direct support, particularly in the sample of SMEs, and that overall large firms benefit proportionally more from both tools.

[12] The Community Innovation Survey has been widely used in many policy evaluation studies.
[13] Note for example that according to the information in Table 1 in 2008 only 12% of large firms in the ESEE sample used both tax credits and direct support, that is, 61 observations maximum, while in the PITEC sample there are about 110 observations.

Table 1. Public support to private R&D

MANUFACTURING FIRMS	PITEC		ESEE	
	SMALL	LARGE	SMALL	LARGE
Total number of firms in the sample in 2008	4503	1074	1512	493
% firms invest in innovation in 2008 (a) (includes R&D and other innovation related expenditures)	64.5	79.6	n.a.	n.a.
% firms invest in R&D in 2008 (in-house and/or external contracting))	57.8	72.5	23.7	70.6
% firms introduced new products/services in 2006-2008	57.9	74.4	n.a.	n.a.
% firms introduced new products, services or new processes in 2008	75.8	84.3	29.3	59.4
% firms that received direct support from the Central Administration in 2008 (a)	8.3	19.2	3.4	20.0
% firms obtained tax incentives in 2008 (b)	21.5	34.6	7.1	31.7
% firms used both types of support in 2008 (b)	4.1	10.6	1.8	12.5
% firms benefiting from tax incentives that also received direct support in 2008 (b)	19.2	30.6	25.0	39.4
% firms having direct support that also claimed tax incentives in 2008 (b)	49.5	55.3	52.7	62.5
% firms received direct support from the Central Administration in 2006-2008 (loans and grants)	15.7	34.1		
% firms obtained tax incentives in 2006-2008	26.8	44.5		
% firms used both types of support in 2006-2008	8.5	23.6		
% firms benefiting from tax incentives that received direct support	31.7	53.1		
% firms benefiting from direct support that also claimed tax incentives in 2006-2008	54.2	69.4		

Notes:

a) Definitions: Innovate = firms that introduce at least one product, or process or service innovation in the period 2006-2008; Invests in Innovation = has positive investment during 2008 in any of the following categories: in-house R&D, external R&D, acquisition of equipment or software, acquisition of external knowledge, training, design and market introduction of innovations.

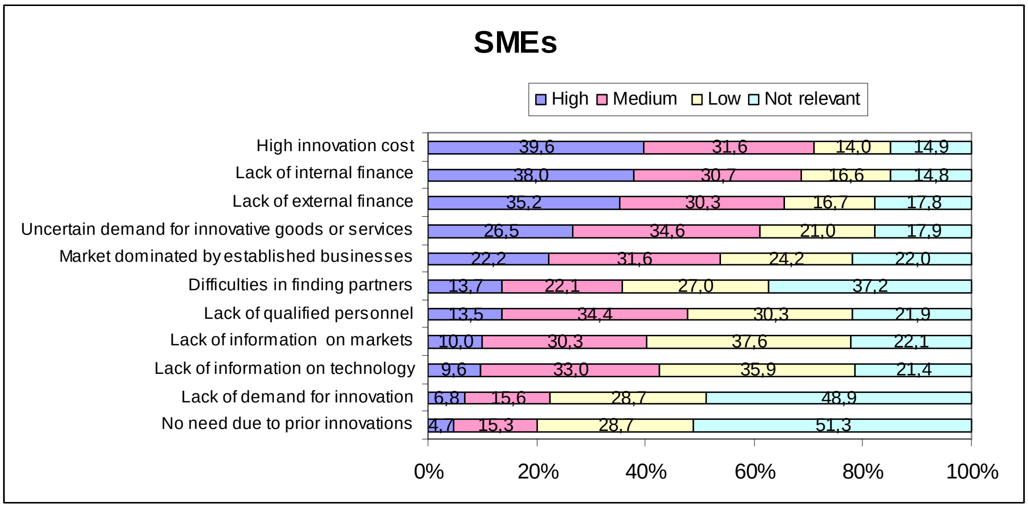
b) In the case of PITEC, the total number of observations may vary for some of the annual variables: in 2008, the number of SMEs is 3912 and the number of large firms is 933.

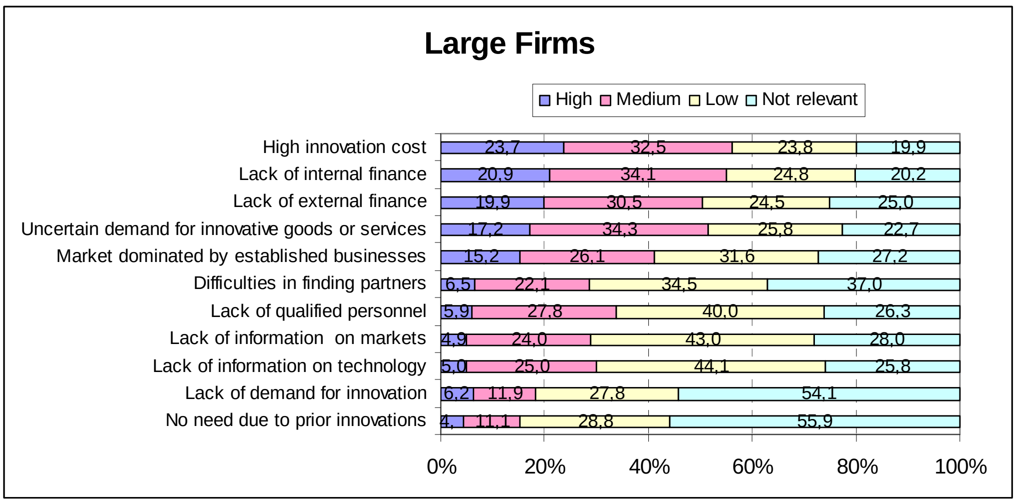
Some questions in the survey are of particular interest because they provide indicators that can be related to potential sources of underinvestment in R&D. Firms are asked to rank a series of potential barriers to innovate according to the degree of importance they have for the firm. In particular, the barriers they are asked about are, among others, financing constraints, both internal and external, and demand uncertainty, which be associated to market failure in the financial market for R&D projects. Quite surprisingly, the list of questions does not include any related to a firm's concern for imitation by rivals, which would provide an indicator of potential spillover effects. Two surveys, the Yale survey (Levin et al 1987) and the Carnegie Mellon Survey (Cohen, Nelson and Walsh, 2000) conducted in the US were designed to obtain information about the firms' view about the effectiveness of some appropriation mechanisms:

legal (patents, trademarks, design or copyright), secrecy, and others (lead time, complementary manufacturing or services), and in some early editions the CIS survey contained similar questions.[14] The current version of the Spanish CIS, however, includes only questions about the actual use of legal protection mechanisms. Finally, the item "market dominated by established enterprises" points to one feature of market structure that may affect potentially a firm's decisions, as predicted by some theoretical models (Cabral and Polak, 2007). Table 2 describes manufacturing firms' perceptions about barriers to innovation.

Table 2 Perceived constraints to innovation in the period 2006-2008

A. Manufacturing Firms





[14] These data have been used for example by Cockburn and Griliches (1988) to study the stock market's valuation of R&D and patents, and more recently by Dushnitsky and Lenox (2005) Ceccagnoli (2009).

Lack of internal and external finance, together with uncertain demand, are the barriers more often perceived as important. SMEs are more sensitive to these than large firms, as well as to access to information on markets or technology. It is worth noting that the simple correlation among the first three barriers is high, while it decreases across the remaining barriers. For large manufacturing firms, the correlation between the importance of internal and external funding is 0.71 (for SME is 0.74) while the correlation between the importance of lack of funding and knowledge factors is around 0.4. We have checked whether firms change their perceptions of barriers between the 2005 and 2008 surveys, and find that about half of the firms keep the same perception. Almost all that change their answer do so only moderately (they may change from level of importance "high" to level "medium", but very few change from level "high" to "not relevant".

3.2. KEY VARIABLES

We use two waves of PITEC: PITEC 2005, where some of the explanatory variables of interest refer to the period 2003-2005, and some to year 2005, and PITEC 2008, where variables refer either to the period 2006-2008 or to year 2008. In order to be able to deal at least partially with potential endogeneity, we use most explanatory variables from PITEC 2005, while dependent variables are from PITEC 2008. We describe next the definition of each variable, indicating in brackets the name assigned to the variable in the tables showing estimation results.

Having claimed tax deductions for R&D and obtaining direct support are our two dependent variables. For *Tax Incentives,* we define a binary variable which equals 1 if the firm declares having claimed tax credits any or all of the years in the period 2006-2008. We believe that since tax credits are subject to carry-forward provisions, using a number of years may provide a more accurate description of behavior than using yearly data. In addition, questions about direct support also refer to a three year period. We nevertheless test for the sensitivity of results to changes in the definition of the dependent variables.

Direct support. We define a binary variable which equals 1 if the firm has applied for and obtained direct funding from the Central Administration in the period 2006-2008. Although firms may obtain direct support from local, central or European administrations, we consider that, since tax incentives are defined at the country level, the appropriate funding source they should be compared to is Central government support.[15] Note that the survey does not provide information on whether a firm applied for but did not obtain direct support. The observed outcome will therefore capture not only the firm's decision but also the public agency's preferences.

Financial constraints. As shown above, firms report the degree of importance of lack of access to internal and to external financing as a barrier to innovation. Because of the observed high correlation between both barriers, we define a single binary variable which equals 1 if the firm considers that either of them has high importance as a barrier in the period 2003-2005. [obfin5]

Appropriability. It is difficult to measure the degree of ex-ante appropriability of R&D investments, in order to test the extent to which it may deter innovation. We know appropriability matters because we observe that firms use the patent system and that there is patent litigation activity. In much existing work, the standard indicator of appropriability has been the use of protection mechanisms. We also take this approach and define a binary variable which takes the value of 1 if the firm has used any of the legal protection mechanisms (copyrights, trademarks, design or patent) in the period 2003-2005 [protect5]. Although this variable might capture past innovation experience, we also will include, as a control, past in-house R&D [idin5], so that we expect that the use of protection methods in the past captures the concern the firm has for potential imitation.

We will also use answers to a question about the importance that the firm gives to information from competitors as a source of ideas for innovation in the period 2003-2005 [Infocomp5] to construct a second indicator of spillovers. Although meant to capture incoming spillovers

[15] There are in Spain 17 regional governments that also provide support for innovation. Although none uses tax incentives, they may provide direct support. Eligibility criteria may differ across regional agencies. See Blanes and Busom (2004).

(Cassiman and Veugelers, 2002), it may also capture the extent of rivalry in the firm's industry.[16] It is interesting to note that only 14% of firms in the sample admit that information from competitors is of high importance to the firm.

Dominant Firm. To capture the possible disincentive effect that the existence of an established dominant firm may have on other firms, we define a binary variable which equals 1 if the firm considers that this is a barrier of high importance. [obdomin5]

New firm. Because young or newly created firms may not have much taxable income, and at the same time, may face financing constraints because they lack reputation, we expect them to be less likely to use tax incentives when intending to generate and introduce innovations, and more likely to apply for direct funding. We define a binary variable to represent a new firm in 2003-2005. [New firm5]

Other barriers are also included in the empirical specification, although they are not the main focus of this research. They are introduced as binary variables, where the value is equal to 1 if the firm considers that a particular barrier is of high importance [obpers5, obinfor5].

Regarding the set of questions on barriers, it is important to note that several studies that have used CIS data for different countries have obtained counterintuitive results. One of the most recently examples is found in a study by the OCDE (2009), which reports the results of a multi-country effort to find regularities in the probability that a firm will innovate and the effects of innovation on productivity.[17] The surprising result from the OCDE study is that it finds for most countries a positive association between most barriers and the probability to engage in innovation.

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[16] Note that in all CIS surveys only innovating firms are asked to answer this item. Czarnitzki et al (2007) also used this question to construct an industry-level index of appropriability.

[17] The same type of firm-level data source and methodology were used for each country; the data being of a cross-section nature.

A possible explanation that has been offered is that innovative firms become more aware of the difficulties associated to innovating than non-innovating firms. This interpretation suggests that self-assessment of barriers may be endogenous to innovative behavior, particularly because in these studies barriers and innovative behavior refer to the same period. An additional problem is that there may be individual-specific heterogeneity in subjective evaluations: some mangers may tend to be optimistic, while others pessimistic. Subjective self-evaluations and subjective expectations, however, are increasingly used in empirical research in other fields.[18] We address these concerns by i) using lagged indicators of barriers and ii) including an additional control variable that aims at capturing the firm's overall perception of difficulties, which is computed as follows: we add the rankings given by the firm to all barriers, and rescale so that it takes values in a 0 to 1 scale [obstAll5]. Larger values indicate that a firm perceives a high overall level of barriers.[19] We expect that this variable will capture the awareness effect, so the importance of individual barriers may be isolated from the firm's overall individual-specific perception.

3.3. CONTROL VARIABLES

The survey included in 2008 a new question related to tax incentives. Each firm was asked whether it took into account existing tax incentives when planning its potential R&D investment. We believe that the answer captures the managers' view on the strategic importance of R&D for their firm. Lacking other indicators of managerial characteristics that might be relevant for innovation decisions, we include this binary indicator as a control variable (plantax).[20]

We include a measure of technological distance of the firm relative to the mean of it sector of activity. The idea is that incentives to innovate are affected by the firm's position relative to the

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[18] See for instance Zafar (2011)

[19] We later check for the robustness of estimates to alternative ways to control for these potential biases.

[20] Note that taking into account tax credit incentives does not predetermine claiming them. Although most firms that do not take them into account do not claim tax credits, 56% of SMEs and 60% of large firms that do take them into account do not claim them. The Pearson correlation between the two variables is .28 for SMEs and .30 for large firms.

technological frontier, as shown in Aghion et al., 2009. Manufacturing is classified into 30 subsectors, and for each we compute the average labor productivity as sales per employee. We then divide each firm's labor productivity in 2005 by the average of its sector (ldistprod5).
We include several variables to control for heterogeneity across firms, most of them binary. Past R&D activity [rdin5], belonging to a group [group5], being a private domestic firm [privdom5], being an exporter [bexp5], location near a science or technological park [park], regional location and industry dummies capturing technological intensity [high, medium high, medium low and low]. We also include as control variables size, measured by the log of the number of employees (lsize5); human capital, measured by the proportion of employees with a higher education degree (humcap5), and the age of the firm (age5).

Table A1 in the Appendix shows the main descriptive statistics for these variables, for SMEs and large firms. Regarding the appropriability measures, we note that around 35% of firms declare having used legal protection mechanisms in 2003-2005. We find surprising, however, that only 14% of firms, whether large or SMEs, consider information from competitors to be of high relevance for their innovation plans. To put this number in perspective, we can compare it to the percentage obtained in the German and French CIS surveys. According to Eurostat, in Germany 17% of manufacturing innovative firms considered this source to be highly important in 2008, against 11% in Spain’s (percentages increase slightly with firm size) and 9% in France. Regarding the importance of conferences, trade fairs and exhibitions, the percentages were 18% for German firms, 5 % for Spanish firms, and 10% for French firms. One possible interpretation of these differences is that innovation management and style differ across countries even among innovative firms.

3.4. ECONOMETRIC APPROACH

Given that we observe whether a firm obtains or not direct support, and whether it uses or not tax incentives, we specify a model with two binary dependent variables. We use a bivariate probit model because it allows for correlation between the random terms across alternatives and is less restrictive than a multinomial model. In addition, a bivariate probit model possibly captures more accurately the decision process by the firm. Tax filing periods may not be the same as grant application and granting periods; in addition, firms may not be able to anticipate their tax position when applying for direct funding. Hence we believe that a multinomial logit approach would not be appropriate in this case.

There will be four possible situations a firm can be in: no support (0,0), no grant but claims a tax credit (0,1), gets a grant but does not claim a tax credit (1,0) and both gets a grant and claims a tax credit (1,1), and therefore four sets of corresponding predicted probabilities, as well as four sets of marginal effects.

The model is the following:

$$S = 1 \text{ if } S^* = b_s X + e_s > c, \quad S = 0 \text{ otherwise} \qquad (1)$$

$$F = 1 \text{ if } F^* = b_f X + e_f > h, \quad F = 0 \text{ otherwise} \qquad (2)$$

Several types of marginal effects may be computed: the marginal effect computed at the mean value of explanatory variables, the marginal effect computed at a representative value of the explanatory variables, and the average marginal effect, which is the average of the marginal effect at each x. For policy analysis, usually the latter is recommended (Cameron and Trivedi, 2009), so these will be our reported results.

We drop from the sample those firms that declare not having an interest in innovating as the main reason for not innovating, because we want to focus on the role of barriers for firms that do have a potential interest for innovating, thus distinguishing between behavior resulting from preferences from behavior resulting from perceived restrictions.

4. RESULTS

4.1 Baseline estimation

We report in Table 3.A and Table 3.B below the estimated average marginal effect of a change in the explanatory variable on each of the four possible situations a firm may be in. We test for equality of coefficients for equations (1) and (2), and the null is rejected (chi-square test not reported in the tables). As specification test, we perform a test for normality of residuals, and do not reject the null.[21]

Because we want to see whether the advantages of these two policy tools differ from the firms' perspective, we first discuss the estimated average marginal effects we have obtained for the probability of using only tax credits and of using only direct support. We find that both for large firms and SMEs, being financially constrained reduces the probability of using only tax credits by about 4 percentage points, while it increases the probability of obtaining direct support by about 2.5 percentage points. These results are consistent with the first two propositions formulated in section 2.

Regarding the appropriability issue, as captured by the use of legal protection mechanisms, we find that for large firms this variable has a significant and negative average marginal effect on the probability of using only tax incentives, but a positive effect on the probability of using only direct support. Since we control for past R&D investment, we believe that this result suggests that firms whose projects have more innovative content and are more concerned about imitation prefer direct support to tax incentives. For SMEs we find a different pattern: those with appropriability concerns are more likely to use either tax incentives alone or both instruments. It is possible that SMEs' innovation projects are on average of an incremental nature and that the cost of applying for direct funding be high relative to the expected probability of obtaining it.

[21] See Chiburis (2010).

Finally, we find that for both SMEs and large firms, being a new firm increases the probability of having only direct support, and reduces the probability of using only tax credits.

We find other interesting differences on the average marginal effect of other variables on these probabilities. Human capital increases the likelihood of using only direct support, but has no effect on the use of tax incentives. A firm's relative productivity has a positive effect on the probability of using tax incentives only, and on the probability of using both types of support. As expected, the variable that captures the overall level of barriers perceived by the firm has a positive effect on the use of any support, and a negative effect on the use of none. Finally, we find different patterns across industries. While industry type does not affect the use of tax incentives, large firms in high-tech industries and in medium-low technological intensity are more likely to use direct support. Among SMEs, firms in high-tech and medium high-tech industries are those more likely to use tax incentives.

We now look at the other two groups of firms: those that do not use any support, and those that use both tax credits and direct support. We find that having previous experience in R&D is the most important determinant of (not) using both kinds of support, both for large firms and for SMEs. For large firms financial constraints do not seem to have a significant effect, while for SMEs they reduce the likelihood of using both tools, and increase the likelihood of using none.

We believe that the significance of past R&D in explaining the use of tax credits (alone or in combination with direct support), but not the use of direct support, points to a characteristic of R&D-related behavior that previous research has identified: persistence.[22] In our sample, 89% of large firms and 73% of SMEs that were investing in R&D in 2005 also invested in 2008. About one fifth of firms switched from not doing R&D in 2005 to doing in 2008 (18% of SMEs

[22] See Mañez-Castillejo, J. A., Rochina-Barrachina, M. E., Sanchis-Llopis, A. and Sanchis-Llopis, J. (2009). Sunk costs or increasing dynamic returns to R&D (through learning effects) might explain persistence.

and 22% of large firms). Many of these "switchers" used some form of public support in the period 2006-2008 (45% of SMEs and 66% of large firms).

Overall, our results suggest that direct support may be more effective to encourage firms that face financial constraints to invest, or invest more, in R&D, while tax incentives may encourage increasing R&D by firms that are not financially constrained and already invest in R&D. Results show clearly that direct support and tax incentives are not substitutes in the sense that they are not driven by the same factors in the same direction.

When we estimate the model including as a proxy for appropriability the importance of information from competitors, which involves using the subsample of innovating firms only, we find differences in the effects for large firms and for SMEs. In the case of large firms, those that give a high importance to this source of information are more likely to use tax incentives only, and less likely to not using any tool. The sign of the effect on using tax incentives only is the opposite of the use of protection, suggesting that both variables capture different things: it is possible that information from competitors is relevant when the intensity of rivalry is high, creating a situation of neck and neck competition, in which case the firm has an incentive to innovate, and therefore claim tax credits. In the case of SMEs, firms that think that information from competitors is important for innovation are more likely to not use any form of R&D support. It is not obvious whether large firms and SMEs interpret the survey question in the same sense, however. The results concerning the role of financing constraints are the same as in the baseline discussed above.

Table 3. A. Large Firms
Bivariate Probit Regression
Average Marginal Effect on the probability of…

	Not having any public support			*Having both types of support*			*Only using tax incentives*			*Only having direct support*		
Variable	Marg Eff	se	p-value	Marg Eff	se	p-value	Marg Eff	se	p-value	Marg Eff	se	p-value
obstAll5	**-.1337**	.048	0.005	.0534	.028	0.090	**.0931**	.043	0.033	-.0127	.018	0.473
obfin5	.0174	.020	0.395	.0076	.012	0.521	**-.0477**	.018	0.010	**.0227**	.011	0.031
obpers5	.0662	.035	0.059	-.0192	.018	0.297	**-.0643**	.028	0.020	.0173	.015	0.254
obinfor5	.0335	.033	0.321	-.0071	.018	0.690	.0594	.033	0.072	**-.0187**	.009	0.046
obdomin5	.0310	.023	0.171	-.0091	.012	0.437	-.0288	.022	0.200	.0054	.009	0.482
obddrisk5	.0149	.026	0.560	**-.0273**	.011	0.014	.0308	.025	0.215	**-.0185**	.007	0.007
protect5	-.0308	.017	0.076	**.0411**	.012	0.001	**-.0436**	.015	0.003	**.0333**	.009	0.000
Ldistprod5	**-.0591**	.013	0.000	**.0283**	.007	0.000	**.0314**	.013	0.015	-.0006	.005	0.887
remusup6	**-.0012**	.001	0.048	**.0011**	.000	0.002	-.0004	.001	0.360	**.0006**	.000	0.011
plancredit	**-.1915**	.015	0.000	**.0632**	.013	0.000	**.1562**	.016	0.000	**-.0280**	.005	0.000
grupo5	-.0215	.020	0.282	.0219	.012	0.075	-.0126	.018	0.472	.0112	.008	0.124
privdom5	**-.0857**	.018	0.000	**.0702**	.014	0.000	-.0066	.018	0.713	**.0222**	.009	0.015
bexp5	**-.0659**	.022	0.003	**.0349**	.015	0.019	.0316	.021	0.140	-.0006	.008	0.942
idin5	**-.3188**	.015	0.000	**.2722**	.025	0.000	.0461	.025	0.067	.0006	.007	0.937
lsize5	**-.0233**	.012	0.054	**.0345**	.004	0.000	**-.0356**	.011	0.002	**.0244**	.003	0.000
New firm5	-.0897	.129	0.486	.0967	.102	0.342	**-.0817**	.037	0.028	**.0745**	.019	0.000
Age5(x10)	.0004	.003	0.914	**.0041**	.002	0.043	**-.0091**	.003	0.005	**.0045**	.001	0.001
parque	-.0566	.053	0.289	.0654	.038	0.087	-.0586	.037	0.114	**.0498**	.024	0.042
madrid	**.0651**	.024	0.007	**-.0467**	.010	0.000	.0009	.023	0.968	**-.0193**	.006	0.003
catal	**-.0461**	.020	0.021	.0006	.011	0.953	**.0630**	.019	0.001	**-.0175**	.005	0.001
andal	**.1453**	.040	0.000	**-.0620**	.017	0.000	**-.0773**	.031	0.014	-.0060	.013	0.659
hightec	**-.1425**	.028	0.000	**.1208**	.022	0.000	-.0093	.028	0.740	**.0311**	.014	0.030
medhigh	**-.0846**	.020	0.000	**.0583**	.015	0.000	.0163	.020	0.404	.0099	.008	0.233
medlow	**-.0693**	.022	0.001	**.0608**	.015	0.000	-.0162	.019	0.389	**.0247**	.009	0.008

Number of observations: 808; Wald chi2(48)=332.09; Log Pseudolikelihood= -850.69; rho= 0.36 with s.e. 0,06.

Table 4. B. SMEs
Bivariate Probit Regression
Average Marginal Effect on the probability of…

	Not having any public support			*Having both types of support*			*Only using tax incentives*			*Only having direct support*		
Variable	Marg Eff	se	p-value	Marg Eff	se	p-value	Marg Eff	se	p-value	Marg Eff	se	p-value
obstAll5	**-.0741**	.025	0.004	**.0427**	.014	0.002	.0023	.020	0.906	.0297	.016	0.062
obfin5	**.0300**	.009	0.002	**-.0113**	.005	0.015	**-.0436**	.006	0.000	**.0248**	.007	0.000
obpers5	.0092	.012	0.468	-.0074	.006	0.261	.0095	.010	0.348	-.01114	.007	0.114
obinfor5	.0109	.013	0.401	-.0036	.007	0.590	-.0148	.009	0.113	.0075	.008	0.349
obdomin5	.0079	.010	0.453	-.0050	.005	0.355	.007	.008	0.741	-.0055	.006	0.359
obddrisk5	-.0007	.011	0.945	-.0030	.006	0.595	.0154	.008	0.073	-.0116	.006	0.048
protect5	**-.0602**	.008	0.000	**.0299**	.005	0.000	**.0310**	.007	0.000	.0007	.005	0.890
ldistprod5	**-.0435**	.005	0.000	**.0179**	.003	0.000	**.0360**	.004	0.000	**-.0104**	.003	0.001
remusup6	**-.0038**	.000	0.000	**.0022**	.000	0.000	-.0000	.000	0.944	**.0002**	.000	0.000
plancredit	**-.2010**	.007	0.000	**.1035**	.0068	0.000	**.1184**	.008	0.000	**-.0208**	.004	0.000
grupo5	**-.0269**	.010	0.009	**.0015**	.0058	0.009	.0038	.008	0.637	.0080	.006	0.209
privdom5	**-.0850**	.017	0.000	**.0442**	.011	0.000	**.0395**	.013	0.003	-.0013	.009	0.891
bexp5	**-.0715**	.010	0.000	**.0353**	.006	0.000	**.0383**	.008	0.000	-.0022	.006	0.704
idin5	**-.2006**	.011	0.000	**.1243**	.010	0.000	**.0669**	.010	0.000	.0093	.007	0.171
lsize5	**-.0687**	.005	0.000	**.0381**	.003	0.000	.0062	.004	0.121	**.0243**	.003	0.000
New firm5	**-.0705**	.028	0.013	**.0393**	.017	0.022	**-.0627**	.016	0.000	**.0939**	.023	0.000
Age5 (x10)	**-.0071**	.002	0.002	**.0040**	.001	0.001	.0002	.001	0.873	**.003**	.001	0.041
parque	**-.1275**	.028	0.000	**.0797**	.020	0.000	.0139	.020	0.485	**.0338**	.017	0.045
madrid	**.0563**	.014	0.000	**-.0248**	.006	0.000	**-.0334**	.011	0.002	.0019	.009	0.839
catal	-.0079	.009	0.383	-.0049	.005	0.302	**.0368**	.008	0.000	**-.0238**	.004	0.000
andal	**.0850**	.018	0.000	**-.0415**	.008	0.000	-.0173	.013	0.199	**-.0261**	.010	0.009
hightec	**-.1325**	.015	0.000	**.0772**	.011	0.000	**.0435**	.013	0.001	.0119	.010	0.215
medhigh	**-.0704**	.010	0.000	**.0291**	.006	0.000	**.0559**	.008	0.000	**-.0145**	.006	0.010
medlow	**-.0259**	.011	0.019	**.0137**	.006	0.027	.0079	.008	0.371	.0044	.007	0.515

Number of observations=3517; Wald chi2(48)=912.67; Log Pseudolikelihood=-3156.4; rho=0.30 with s.e.=0.03.

4.2 ROBUSTNESS ANALYSIS

We have performed alternative estimations to check for the robustness of our results to a series of changes. These are the following. First, we have reestimated the model adding a binary variable for low financing constraints and using different subsamples of firms: a subset of firms that introduced products new to the market in 2005 or before, because this particular subset may be more sensitive to appropriability issues; a subset of firms that did R&D in 2005, and subset of firms in high tech and medium tech manufacturing sectors. Results remain basically unchanged across subsamples for SMEs, and for the first subsample in the case of large firms. For the subsample of large firms that did R&D in 2005, and for the subsample of firms in the high tech and medium high tech industries, financial constraints are not associated to the likelihood of using any of these policy tools. This constraint remains significant for SMEs.

Second, we re-estimate the model dropping some outliers for one of the continuous control variables, relative productivity, and find that results remain basically unaffected.

Third, we change the definition of dependent variables, tax credits and direct support. Instead of using binary variables referring to the 2006-8 period, we use binary variables referring to year 2008 only. In addition, regarding direct support the question asked is not identical. For the three year period, firms are asked whether they received any direct support for innovation activities, including loans and grants. The question referring to year 2008 includes only grants for in-house R&D. We find that the main estimates of interest remain stable.

Finally, we change the way we calculate constraints, partly because we fear that correlation among the set of barriers to innovation may affect standard errors. We define for each barrier the ratio between the ranking for that barrier and the average value for all barriers, as perceived by the firm. We find that the main results are not affected. [23]

5. CONCLUSION

Our analysis has addressed the preferences of Spanish firms regarding the use of two tools of public support to private R&D activities, linking them to potential barriers to innovation, with special focus on the role of financial constraints and appropriability indicators. Using data from PITEC for the periods 2003-2005 and 2006-2008, we have estimated the determinants of the likelihood of using these tools jointly, in isolation or none.

Results support the main hypothesis that tax incentives and direct funding are not perfect substitutes, because financing constraints affect differently the likelihood of using each instrument. In particular, our findings show that the probability to use tax incentives falls when firms face financial constraints, while the likelihood of using direct funding increases. There are differences as well regarding the effect of appropriability, as measured by the use of legal forms of protection. The direction of this effect is not the same for large firms and for SMEs. While large firms that have used protection methods are less likely to use tax incentives, and more likely to use direct support, SMEs that protect their ideas are more likely to use tax incentives.

These results do suggest there is a link between the nature and extent of market failures related to R&D and the use of these two tools of public support to private R&D, a point not previously made in the literature. However, while the survey questions related to financial constraints are unambiguous, the issue of appropriability remains very difficult to evaluate with the questions currently used in the survey. Some innovation project level information could be helpful in that regard, as well as introducing questions similar to those used in the Yale and Carnegie Mellon surveys regarding the importance of secrecy and lead time.

[23] All robustness results are available on request.

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APPENDIX

Table A1. Descriptive Statistics

		SMEs						LARGE					
	Variable	**N**	**mean**	**sd**	**min**	**p50**	**max**	**N**	**mean**	**sd**	**min**	**p50**	**max**
Awareness of constraints	obstAll5	3685	.507	.224	0	.523	1	835	.424	.232	0	.428	1
Financially constrained	obfin5	3685	.389	.487	0	0	1	835	.241	.428	0	0	1
Lack of personnel	obpers5	3685	.133	.340	0	0	1	835	.069	.254	0	0	1
Lack of information	obinfor5	3685	.135	.342	0	0	1	835	.082	.275	0	0	1
Dominant firm	obdom5	3685	.206	.405	0	0	1	835	.158	.365	0	0	1
Demand risk	obddrisk5	3685	.206	.404	0	0	1	835	.134	.340	0	0	1
Appropriability_a	protect5	3685	.355	.478	0	0	1	835	.388	.487	0	0	1
Appropriability_b	Infocomp	3439	.137	.344	0	0	1	736	.138	.346	0	0	1
Log of Relative productivity*	ldistprod	3685	-.331	.822	-13.38	-.309	2.82	835	-.041	.706	-4.719	-.0189	2.333
Share of highly educated employees*	humcap	3685	18.65	18.48	0	13	100	835	13.42	14.44	0	9.4	100
Take into account tax incentives	plantax	3912	.411	.492	0	0	1	933	.533	.499	0	1	1
Group membership*	group5	3685	.237	.425	0	0	1	835	.748	.434	0	1	1
Private domestic firm*	privdom5	3685	.927	.258	0	1	1	835	.665	.471	0	1	1
Exporter*	bexp5	3685	.711	.452	0	1	1	835	.843	.363	0	1	1
Did in-house R&D*	rdin5	3685	.768	.421	0	1	1	835	.717	.450	0	1	1
Log of number of employees*	lsize5	3685	3.606	.956	0	3.63	7.15	835	6.00	.717	4.060	5.855	9.232
New firm*	new_5	3685	.023	.150	0	0	1	835	.009	.077	0	0	1
Age*	age5	3735	22.94	17.85	0	19	166	904	32.95	22.75	0	30	170
Located in technological park	park	3912	.020	.143	0	0	1	933	.027	.164	0	0	1
Firm located in Madrid	madrid	3912	.077	.267	0	0	1	933	.173	.378	0	0	1
Frim located in Catalonia	catal	3912	.296	.456	0	0	1	933	.302	.459	0	0	1
Firm located in Andalusia	andal	3912	.052	.222	0	0	1	933	.039	.195	0	0	1
Firm in high tech sector	hightec	3912	.097	.296	0	0	1	933	.117	.322	0	0	1
Firm in med-high sector	medhigh	3912	.340	.473	0	0	1	933	.305	.460	0	0	1
Firm in med-low sector	medlow	3912	.261	.439	0	0	1	933	.270	.444	0	0	1

Note: all variables marked * refer to year 2005; otherwise they refer to the period 2003-2005