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Tax incentives… or subsidies for business R&D?

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Abstract We study whether firms' actual use of R&D subsidies and tax incentives is correlated with financing constraints -internal and external- and appropriability difficulties and investigate whether both tools are substitutes. We compare the use of both policies by SMEs and by large firms and find significant differences both across instruments and across firm size. For SMEs, financing constraints are negatively correlated with the use of tax of credits, while they are positively associated with the likelihood of receiving a subsidy. The use of legal methods to protect intellectual property is positively correlated with the probability of using tax incentives, but not with the use of subsidies. For large firms external financing constraints are correlated with instrument use, but results regarding appropriability are ambiguous. Our findings suggest that (1) direct funding and tax credits are not perfect substitutes in terms of their ability to reach firms experiencing barriers associated to market failures; (2) one size may not fit all in innovation policy when the type or intensity of market failure differs across firm size, and (3) subsidies may be better suited than tax credits to encourage firms, especially young knowledge-based firms, to start doing R&D.

Keywords SMEs · Innovation · R&D · Tax incentives · Subsidies · Policy mix

JEL Classifications H25 · L26 · L60 · O31 · O38

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1 Introduction

Tax incentives and direct funding through grants and loans are two policy instruments currently used in many countries to stimulate business R&D. While direct public funding of private R&D has a long tradition, tax incentives have spread gradually across countries. OECD estimates of the relative weight of each instrument as a share of GDP in 2009 show that Canada, The Netherlands and Japan rely mostly on tax incentives. France, Denmark, Spain, the United Kingdom and the United States use both instruments simultaneously, while exclusive reliance on direct funding is still preferred in Sweden, Finland or Germany (OCDE 2011a).

The main economic rationale for using any of these tools rests on the notion that market failures reduce or may even deter private R&D investment. These failures derive mostly from knowledge spillovers and from asymmetric information. The first lead to revenue appropriability difficulties as a result of imitation by rivals; asymmetric information between investors and inventors may result in financing constraints.[1] Sunk costs generate additional barriers to starting R&D activities. Extensive empirical evidence supports these hypotheses. Which particular form public support should adopt to correct for market failure is, however, a matter of debate. Do tax credits and subsidies succeed in reaching in practice firms affected by these sources of market failure? Are there any conditions where one is to be preferred to the other, or is there an "optimal mix" of both instruments?[2] While there is substantial empirical research that has separately estimated the effects that R&D subsidies and R&D tax incentives have on private R&D investment and on some outcomes, to the best of our knowledge an explicit and comparative analysis of both tools remains to be done.

We aim at providing evidence on these questions by analyzing who uses R&D tax credits and direct funding when both are available to firms. Research has so far focused on testing whether public support increases or on the contrary crowds out private R&D investment, supplying estimates of the degree of additionality or "bang for the buck". While testing for crowding out (negative additionality) is certainly a highly relevant yardstick to assess public support, positive additionality may not be necessary nor sufficient for evaluating its effectiveness. We need to know whether the use of each of these tools, and the extent of additionality, are related to lack of appropriability and/or to financing constraints deterring innovation activities.

To illustrate this point, assume that an impact evaluation with firm-level data finds that subsidy supported firms on average barely increase their private R&D investment, or that the share of sales of new products, a standard indicator of innovation outcomes used in the literature, is not significantly different from a control group of non-supported firms. Estimated additionality would be close to 0, yet should the conclusion be that the policy is not effective? Possibly not if subsidized firms applied for and obtained support precisely in anticipation of imitation (high spillovers), and introduce innovations that are quickly imitated. In the case of tax credits, observing that firms increase their private R&D investment may not be sufficient to claim this policy to be a success. While firms whose R&D projects are well protected against imitation will be able to claim the tax credit and use it to increase their investment in other appropriable projects (producing positive additionality), those firms whose potential projects are affected by high spillovers and generate low private profits may be left out.

Consequently, to evaluate each of these two forms of public support we should ask directly whether their use is associated to the presence of these market failures. We claim that if limited appropriability and financing constraints affect a firm's R&D investment decisions, and if policies are designed to target this type of firms, we then should observe a positive correlation between indicators of these barriers as perceived by a firm and the probability that it will use an R&D tax credit or have direct support or both. If both tools are substitutes, these correlations should be similar in sign and magnitude.

We contribute to the literature in several respects. First, we explicitly ask whether program participation is related to indicators of sources of market failure. We believe that this may provide useful insights for assessing the effectiveness of innovation policies and for interpreting results that are obtained in impact studies. Second, we compare the use of subsidies and tax incentives by firms that can potentially use both and test whether both policies exhibit similar correlation patterns between indicators of market failures and the actual use of each tool. This provides insights about the equivalence of both tools. Finally we investigate whether access to each type of public support differs for large firms and SMEs.

Using firm-level data from two waves of the Spanish Community Innovation Survey (CIS), 2003–2005 and 2006–2008, which provide information on the use of R&D subsidies and R&D tax credits, we find some differences both across tools and firm size. SMEs facing financing constraints (whether internal or external) are less likely to use R&D tax credits. Instead, they are more likely to use direct public

[1] Appropriability refers to the degree to which a firm captures the value or returns created by innovation (Cassiman and Veugelers 2002).

[2] The concern about the design of an optimal policy mix is expressed in OECD's documents on innovation policy (see OECD 2010, chapter 4) and in the testimony by the OECD for the US Senate Committee on Finance, OECD 2011b.

funding exclusively. Regarding appropriability, SMEs that use legal methods to protect their intellectual property are more likely to use tax incentives or both instruments. For large firms we also find that financially constrained firms are less likely to use tax incentives, but use of each type of support is apparently unrelated to appropriability as captured by use of IP protection. What is common to both types of firms is that previous R&D experience is highly correlated with the use of tax incentives, but much less (for SMEs), or not at all (for large firms), with the likelihood of using subsidies only. Young knowledge-intensive firms, whether small or large, are as well more likely to have access to grants than to tax credits. These results suggest that subsidies, unlike tax credits, may be able to induce new R&D investment and thus affecting R&D decisions at the extensive margin.

From our results we can infer some policy implications: direct funding and tax credits, given their current design, do not have the same ability to address the main sources of private R&D underinvestment, and hence are not perfect substitutes. Direct support to SMEs seems to be a more appropriate tool for addressing underinvestment related to market failures. Some key differences between both tools may explain this result, as we discuss below.

The paper is organized as follows: in the next section we review previous work most closely related to our research question. In Sect. 3 we describe some relevant facts revealed by the data. In Sect. 4 we discuss some hypotheses regarding the use of R&D tax credits and direct support. In Sect. 5 we present our empirical analysis, while in Sect. 6 we perform some robustness tests. Section 7 concludes.

2 Previous evidence

Many firm level studies provide evidence that productivity responds both to a firm's own investment in R&D as well as to other firms' R&D, the latter being a measure of R&D spillovers across firms (Hall et al. 2010). There is also evidence that SMEs face an innovation financing gap, while results are mixed for large firms (Hall and Lerner 2010). Even if the case for intervention seems to be well established, available policy instruments may have drawbacks. Direct public support through subsidies reduces the private costs of investing in R&D, but places high information requirements on the public agency awarding them and may allow for discretionary behaviour. Tax credits and allowances may appear to be a neutral, simple and non-interfering tool, but the specific design is important, as they might be easily claimed for projects that yield high private returns and would have been carried out anyway, while socially valuable projects might not be developed. Empirical evaluation of the take-up and impact of both tools may thus help to improve policy design.

A substantial volume of empirical research has estimated the impact (additionality) of direct support and of R&D tax incentives on the level of private R&D investment. The effects of each tool have been studied mostly in isolation, with the few exceptions discussed below. Where firms use both, individual estimates may in fact overestimate additionality. Regarding tax incentives, some findings are of interest. The first is the differential effect on private R&D across firm size. Lokshin and Mohnen (2012) estimate that 1$ of foregone tax generates 3.2$ of private R&D in the case of SMEs, while it generates 0.80$ of investment by large firms. The second is the positive relationship between use of tax credits and a firm's financial capability found by researchers who use propensity score matching methods (PSM) to estimate additionality. These methods entail the estimation of a program participation equation, and where proxies for the firm's global financial capacity are taken into account, they are found to be positively related to participation (Corchuelo and Martínez-Ros, 2010; Czarnitzki et al. 2011; Kobayashi 2013).

Propensity score methods have also been widely used to assess the effects of direct support on business R&D or other outcomes (Cerulli 2010). Program participation equations typically include as determinants firm size and other firm characteristics, but as with tax credits, the link to sources of market failures has not been investigated.[3] Gelabert et al. (2009) come closest to this by looking at the relationship between additionality of

[3] Project and firm level data have been used by Huergo and Trenado (2010) to study the allocation process of subsidized loans in Spain, distinguishing between the firm's application and the agency's awarding decisions. They find that exporters are more likely to apply, while conditional on applying the agency is more likely to award support according to the firm's technical capability and export potential. Differences between SMEs and large firms and the role of appropriability are not considered. Hussinger (2008) uses a credit rating index and finds that firms with better rating are more likely to obtain direct public funding in Germany.

direct support and appropriability, finding a counterintuitive inverse correlation. Takalo et al. (2012) are the first to provide a theoretical model for the R&D subsidy allocation process, including firm's application and agency's granting decisions, and the private R&D investment decision. Their model allows them to make some inferences about the role of spillovers in Finland's R&D subsidy programs. Using firm and project level data, they find that technical challenge is the most significant and important variable in the agency's subsidy rate decision, and that support generates benefits beyond private returns. However, financing constraints are assumed away and a comparative analysis with R&D tax credits cannot be performed because this instrument is not used in Finland.

Only a small number of authors estimate and compare the additionality of both types of support. Haegeland and Moen (2007) find that in Norway the additionality of tax credits is higher than the additionality of grants. Berubé and Mohnen (2009) find that Canadian firms that claim tax credits and also receive subsidies introduce more new products and made more world-first product innovations than firms that use tax credits only. Marra (2008) finds that tax credits increase private investment more than subsidies for manufacturing firms in Spain. Finally, Foreman-Peck (2012) finds that SMEs that receive support in the UK grow faster, and that both types of support increase innovation.

Why additionality varies across tools, and whether firms that participate in each of these programs are those more likely to experience financing constraints or appropriability difficulties is not investigated in these studies. We believe that paying more attention to who has access to support is a relevant issue in assessing the ability of each policy to address R&D related market failures As discussed above, estimates of input or output additionality do not provide sufficient insights into policy effectiveness beyond discarding crowding-out effects. Tax incentives and direct support differ in some dimensions that are important to firms and affect their ability to offset market failures. Before we discuss this thoroughly in Sect. 4, we first briefly describe some facts revealed by our data concerning policy use.

3 The data: some facts

R&D tax incentives and direct support have been simultaneously available to firms in Spain at least since the early eighties, although a major legal change increasing tax incentives took place in 1995. Tax incentives are mostly provided through deductions from the firm's corporate tax liability. There is a (small) tax credit for innovation (non-R&D) expenditures as well. From 2006 to 2008, the total volume of tax credits was somewhat above €300 million yearly. The number of firms claiming tax credits was 3,621 in 2006, falling to 3,150 in 2008.[4] Direct support, mostly channelled through a public agency (CDTI), provides grants and loans for firms' R&D and innovation projects. In 2006 the volume of support provided by CDTI was €800 million (€1,090 million in 2007, and €766 million in 2008) and about 1,000 projects were funded. Direct support is thus at least twice as large as the volume of tax credits, although it reaches a smaller number of firms.

Our empirical analysis is based on data from the PITEC, a firm-level panel data set developed by the Spanish Statistical Office (INE) as a by-product of the European Community Innovation Survey (CIS).[5] It collects information related to innovation activities of firms with more than ten employees in manufacturing and service industries. Answering the survey is mandatory in Spain, and the response rate is high (about 90 %). We use data from the surveys conducted from 2005 to 2008, and focus on manufacturing firms. Some questions refer to a 3 years period (2003–2005; 2004–2006; and so on) while others refer to the survey year. In particular questions on barriers to innovation and use of intellectual property protection mechanisms, which will be central in our analysis, refer to a 3-year period.

Firms are regularly asked whether they receive R&D subsidies (non-reimbursable funds) from each different level of the public administration. In 2008 the survey included some questions related to R&D tax incentives as well: whether the firm took into account the potential tax credit when planning R&D

[4] In the Appendix we provide a more detailed account of both policy tools and information sources. Using information from the National Statistical Institute on the number of firms that conduct in-house R&D activities, we estimate that the number of claimants is about 25 % of potential claimants.

[5] PITEC is the acronym for "Panel de Innovación Tecnológica en las Empresas". A description of the survey can be found at the following link (in Spanish): http://www.ine.es/. Mairesse and Mohnen (2010), discuss some of the Community Innovation Survey features and shortcomings.

investment, and whether it had claimed tax credits in 2008 and each of the previous 4 years.[6]

We classify a firm as having an R&D subsidy if it received one during the period 2006–2008, and similarly for tax incentives. We split the sample in two firm-size groups, SMEs and large firms, both for statistical and conceptual reasons.[7] We observe four types of firms according to the use they make of each policy tool. 62 % of SMEs (45 % of large firms) did not use any support during the period 2006–2008, while 9 % of SMEs (20 % of large firms) used both. We also observe that some use only subsidies (8 % of SMEs; 10 % of large firms) and some only tax credits (21 % of SMEs and 26 % of large firms). Overall, using tax credits is more frequently observed among large firms.[8]

How do these patterns arise? A preliminary description suggests that the type of support used and firms' perception of barriers to innovation might be correlated. In the survey firms are asked to rank a series of potential barriers to innovate, among them financing constraints, both internal and external, demand uncertainty and the extent to which the market is dominated by established firms. Lack of internal and external finance, together with uncertain demand, are the barriers most often perceived as important. SMEs are more sensitive to all barriers than large firms. The simple correlation among the first three barriers is high (about 0.7), while it decreases across the remaining barriers.

Table 1 below shows the percentage of firms that considered each barrier to be of high importance in 2003–2005 by support status in 2006–2008, as well as their use of legal intellectual property protection mechanisms. This description suggests a positive correlation between the type of support used and firms' perception of financing constraints, particularly for SMEs. It also appears to be correlated with the use of protection mechanisms, past R&D experience and human capital. In the next section we provide some arguments as to why these patterns may arise.[9]

4 Direct and indirect R&D support: some differences and hypotheses

We believe that some differential features related to the design and timing of R&D subsidies and tax incentives may have an influence on when a firm is more likely to benefit from each.[10] We next describe these features and their implications, and then sketch the firm's decision problem, linking it to the observed patterns of instrument use.

4.1 Features of direct and indirect support

Direct public funding is obtained only if the firm submits an application to the public agency and the agency decides favourably after screening and ranking the proposals. The requirements set by subsidy awarding agencies are usually related to the innovative content of the proposal, the technical ability of the firm to carry it out, and the project's market potential.[11]

[6] The total number of firms that declare using tax incentives in 2008 in PITEC is 1742 (manufacturing and services). We estimate that our sample covers thus about 55 % of all claimants that year.

[7] In the PITEC different sampling procedures are used for large firms (200 or more employees) and SMEs. All large firms are surveyed. For SMEs, all firms that have received any form of public support for R&D, have reported R&D expenses in the current or past years and a stratified random sample of non-R&D performing firms are surveyed. Innovators are over represented in this sample: over 50 % of SMEs in the PITEC sample invest in R&D against 13 % in the population, according to INE.

[8] According to data provided by the tax authorities (Agencia Estatal de la Administración Tributaria and Dirección General de Tributos), large firms' share of total R&D deductions is about 73 %.

[9] In our sample, not all firms that were investing in in-house R&D in 2005 claimed tax credits in subsequent years (36 % of SMEs and 57 % of large firms did). Many firms, mostly SMEs, declare that the main reason for not claiming is that their R&D expenditure is too low; while some large firms declare that their type of R&D did not fit eligible expenditures.

[10] While some theoretical literature has compared patents, prizes and subsidies as innovation policy tools (Wright 1983; Fu et al. 2012), to the best of our knowledge tax incentives have not been explicitly included in these comparisons.

[11] There are significant differences across countries in the specific design of direct support. In the United States, the description of SBIR program, which targets SMEs (see http://www.sbir.gov) states that R&D risk and fixed costs are key motivations for the program. Public agencies involved with the program set R&D topics in solicitations. In Finland, the public agency Tekes values the degree of novelty and research intensity of projects but does not appear to target particular fields (http://www.tekes.fi). The Spanish case is similar to the Finnish. See Huergo and Trenado (2010) for a detailed description of the Spanish case.

Table 1 R&D support status in 2008 and innovation barriers

	SMEs $N = 3{,}626$				Large firms $N = 811$			
	No support	Only subsidies	Only tax credits	Use both	No support	Only subsidies	Only tax credits	Use both
Innovation barriers (% firms)								
Financing Constraints								
All	40	48	30	39	23	36	22	29
Internal	32	41	21	28	15	27	12	17
External	29	33	23	31	17	33	15	24
Demand risk	21	19	20	20	11	20	13	16
Dominant firms	20	19	20	25	15	20	17	12
Lack of information	14	10	11	15	7	13	8	12
Lack of personnel	14	10	12	13	7	11	6	7
Protect innovations	30	44	44	48	27	54	41	52
Firm features								
Firm size	50	51	63	70	505	729	527	819
No. employees								
Employees with higher education (%)	15	30	20	28	10	17	14	15
Relative productivity	.88	.98	1.1	1.0	1.1	1.1	1.3	1.3
Did R&D in 2005 (%)	68	91	89	95	46	92	85	96

Firms that do not intend to innovate because they declare that innovating is not necessary are dropped from the sample. Lack of information includes both market and technological information. Relative Productivity is computed as the ratio of firm's sales/employee over the industry mean

The agency may rate projects along several additional dimensions, such as ability to contribute social value, collaboration with public research labs or with universities, and financing constraints. If the agency is able to assess these items, it can tailor the magnitude and duration of direct support to the particular features of the project, although a maximum subsidy rate is often set in practice. The firm runs the project once funding has been approved, and the agency provides a down-payment to start it.[12] Subsidy application may not be costless, as preparing a good proposal requires at least the use of time and qualified labour; it also entails disclosure of information.

R&D tax incentives do not require the approval of a specific project by a government agency. Provided as tax credits –a deduction from the firm's tax liability- or as tax allowances—a deduction from taxable income-, they are targeted to all R&D performers, irrespective of project features and quality as long as expenses qualify as a research and development according to the tax code. To be able to benefit from it the firm must have a positive tax liability, unless a refund system is established.[13] The cost of claiming tax credits may be lower than the cost of applying for subsidies, since a firm must file for taxes every year anyway; it just has to keep proper records.

Tax credits deducted from the corporate tax liability are in fact an ex-post prize for successful innovation outcomes, while when they are applied to the corporate wage and social contribution taxes they act as a subsidy to R&D effort, regardless of the project's outcome. This difference may be important for firms' decisions,

[12] Once the firm has had a project proposal approved, it may be able to obtain additional funding from the private sector. Agency approval may act as a quality certification, as shown in Takalo and Tanayama (2010).

[13] This obviously depends on the specific design of R&D tax incentives. In Spain and France firms that invest in R&D can obtain a deduction from their tax liability, which therefore has to be positive at some point (both systems contain carry-forward provisions). In the Netherlands the R&D deduction is applied to wages paid to R&D staff, and in the UK SMEs can get a cash refund; the deduction is thus independent of the firm's tax position in these countries.

because in the first case the firm's tax position is uncertain at the time of making the R&D decision. We will focus here exclusively on the possible differences between subsidies and tax credits applied to the corporate tax liability because this matches the legal environment that firms in our sample face.

This description points at several potentially relevant differences between both tools in three respects: (1) actual eligibility; (2) magnitude and certainty of support, and (3) timing of support.[14] In terms of eligibility, while all privately profitable R&D projects will qualify for a tax credit, it is likely that only a subset exhibiting high degree of novelty, risk or spillover capacity would qualify for a subsidy. Conversely, of those qualifying for a subsidy, some may not be able to claim tax credits if expected private profits are low and unable to lead to a positive or significant deduction.

With respect to the magnitude and certainty of support, although both tax incentives and subsidies reduce the cost of R&D, subsidies provide more certainty on the extent of this reduction for the firm. If awarded, the firm knows the amount of support it will get before it starts the project, whereas in the case of tax incentives effective support depends on the firm's ex-post tax position. The actual tax liability may turn out to be smaller than the potential tax credit, especially in the case of SMEs and young firms. In addition, the type and amount of subsidy may be tailored to specific features of the project, i.e., whether it generates spillovers (with grants), or faces financing constraints (with loans), or both. Tax credits instead will be higher in absence of spillovers and financing constraints.

Timing of support: subsidies usually provide upfront funding for R&D projects, while tax incentives provide a compensation after the project has been privately funded. To benefit from a tax credit, and independently of whether they are applied to the corporate tax or to wage or social security contribution taxes for R&D employees, the firm must be able to fund the project in advance. As young firms and SMEs may often lack internal and external funding, they are less likely to benefit from this instrument.[15] In addition, R&D subsidies not only provide up-front funding for R&D, but also may provide a signal of the quality of a project to potential private investors. Subsidies may therefore have a certification effect, unlike tax credits, facilitating access to external finance (Meuleman and De Maeseneire 2012).

4.2 Firms' R&D decisions and policy instrument use

We can approximate the firm's decision problem that generates the observed program participation patterns as follows. Assume that a firm produces a standard product and obtains profits π_0 without conducting R&D. It will decide whether to conduct R&D at time t, leading to a new product or a new process, depending on the expected stream of additional profits. To do so it will take into account the possibility of obtaining a grant and/or a tax credit, and will have expectations about the likelihood and size of each type of support. Applying for and obtaining each type of support might involve some costs (preparing a grant application requires time; claiming tax credits involves additional record keeping costs and may increase the risk of a tax inspection).

Each R&D investment project x_{it} will be characterized by a specific level of spillovers. In the case of R&D leading to product innovation, appropriability is full when the firm faces the shifted market demand for the product generating revenues $\overline{R}_t$. If imitation is fast and substantial, the firm will face only a share of the demand and revenues will be smaller. Let λ_{it}, be a parameter capturing the degree of appropiability, with $0 \leq \lambda_{it} \leq 1$. We can write firm's expected revenue as: $R^e_{it} = \lambda_{it}\overline{R}_t(x_{it}, z_{it})$, where z_{it} a vector of firm and industry characteristics. The firm may face as well R&D financing constraints, captured by a parameter $\theta_i \geq 0$, the risk premium it has to pay. The firm's R&D investment cost depends on the market interest rate, r, and on θ_{it},: $C_{it} = (1 + r + \theta_{it})x_{it}$. We also should allow for the possibility that the firm has to incur R&D sunk costs, F, if it has not previously invested in R&D. We can define a dummy variable d_{it-1} that indicates previous R&D investment status.[16]

[14] A similar ongoing discussion in the US concerns provision of support for college education through tax credits versus through grants or loans. See Long (2004).

[15] Hajivassiliou and Savignac (2011) find evidence suggesting that constrained firms are less likely to start innovative projects.

[16] Previous empirical work (González et al. 2005; Mañez-Castillejo et al. 2009; Arqué and Mohnen 2012), provides evidence that sunk costs are an entry barrier for some firms. Aw et al. (2011), who study the relationship between R&D and exporting in a dynamic setting, also find evidence consistent with the presence of sunk costs in both activities.

The firm has beliefs about the agency's subsidy granting rules. If the agency behaves as a benevolent social planner, the firm expects the subsidy to depend negatively on the degree of appropriability (i.e., positively related with external benefits generated by the project), and positively on financing constraints, thus will be given by $S^e(\lambda_{it}, \theta_{it}; q_{it}, x_{it})$ with $\frac{\partial S^e_{it}}{\partial \lambda_{it}} < 0, \frac{\partial S^e_{it}}{\partial \theta_{it}} > 0$ where q is the quality (novelty) of the project.[17] In addition, the firm takes into account the expected present value of the tax credit it could claim conditional on the corporate tax liability being positive. Since taxable income (gross profits) is a function of λ_{it} and $\theta_{it,}$ the expected size of the tax credit, given a statutory deduction rate δ, is given by $T^e_{t+1} = E(\delta x_{it} | (R^e_{it}(\lambda_{it}, x_{it}, z_{it}) - (1 + r + \theta_{it})x_{it} - F_i(1 - d_{it-1}) > 0))$. The present value of the expected tax credit $\beta T^e_{t+1}(\lambda_{it}, \theta_{it}, x_{it})$, where β is the discount rate, will increase with appropriability, and decrease with financing costs: $\frac{\partial T^e_{it}}{\partial \lambda_{it}} > 0, \frac{\partial T^e_{it}}{\partial \theta_{it}} < 0$. Figure 1 illustrates the expected subsidy and expected tax credit rates per 1$ invested in R&D as a function of λ, for a given level of θ. As θ increases, the expected tax credit function would shift downwards.

The firm's expected profit function in period t is then:

$$\widetilde{\Pi}^{\mathrm{RD}}_{it} = \left\{ \begin{array}{l} R^e_{it}(\lambda_{it}; x_{it,} z_{it}) - C_{it}(r_t, \theta_{it}; x_{it}) \\ + S^e_{it}(\lambda_{it}, \theta_{it}; q_{it}, x_{it}) + \\ \beta T^e_{it+1}(\lambda_{it}, \theta_{it}; x_{it}) - F_i(1 - d_{i,t-1}) \end{array} \right\} \quad (1)$$

The firm will decide whether to invest in R&D and how much to invest so as to maximize expected profits. The discrete decision will be a function of the expected subsidy, expected tax credit and expected fixed costs. Let's define expected gross profits without support and without sunk costs: $\Pi_{G,t} = \lambda_{it}\overline{R}(x_{it}, z_{it}) - (1 + r + \theta_{it})x_{it}$. There will be the following cases, depending on the values of λ, θ, F and $d_{i,\ t-1}$:[18]

(a) With high appropriability and no financing constraints ($\lambda = 1$ and $\theta = 0$), the firm's expected subsidy will be 0. There will be some level of R&D investment such that expected gross profits are positive, and so will be the expected tax credit. If the firm was investing in R&D in the previous period, it will not have to incur sunk costs. It will then perform R&D and claim the tax credit. If it was not previously investing, then it will invest in R&D only if $\Pi_{Gt} + \beta T^e(\lambda, \theta; x) > F$. We thus expect firms with high appropriability and with previous R&D experience to claim R&D tax credits. These firms would be unlikely to obtain subsidies if the agency's goals are mostly dealing with market failures.

(b) For $\lambda = 1$ but $\theta > 0$: as θ increases, gross profits fall. For small values of θ, the expected tax credit may still be positive. In this case for some firms it may still be optimal to invest in R&D and claim the credit. However, for large values of θ, gross profits will be small or negative, so the tax credit could not be claimed. In that case a firm would invest only if the agency provides support to

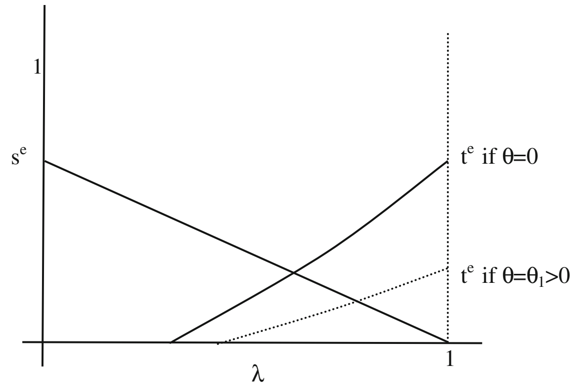

Fig. 1 Expected grant and tax credit rates. *Note* In practice agencies set a maximum subsidy rate below 1. There may also be a minimum subsidy rate. The figure shows that for low values of λ a firm will use only subsidies, conditional on positive expected profits, while for higher values it will use both. For values close to 1 a firm may use only tax credits, if either the agency sets a minimum subsidy level or the costs to the firm of applying are not negligible

[17] EU communications concerning innovation policy appeal to market failures as one of the motivations for public support. This is public information, so it is not unreasonable to formulate the expected subsidy this way. In addition, public agencies usually publish annual reports and other periodical publications that provide some information about the support that has been granted. For instance in Spain the agency publishes yearly a list of projects and firms that have obtained support; from this information, as well as on agency information describing eligibility for support, a firm can build realistic expectations regarding the likelihood of obtaining a grant and/or a loan for a project.

[18] To simplify notation, subscripts are omitted hereafter.

financially constrained firms, enabling them to use the tax credit in addition.[19]

(c) For the extreme case where $\lambda = 0$, independently of the value of θ, the optimal R&D investment would always be 0 unless the expected subsidy at least covers the whole project cost as well as the sunk cost if the firm did not invest in R&D previously. In those cases the firm would perform R&D only if granted a subsidy.

(d) When $0 < \lambda < 1$, the expected subsidy is positive but falls as λ increases. Figure 1 suggests that for some intermediate values of λ, and in the absence of financing constraints, a firm will be able to use both instruments. However, as financing constraints increase (large θ), the firm will rely mostly on subsidies. As λ falls, the expected tax credit falls independently of θ, so the firm will rely more on subsidies only.

(e) Firms will be unlikely to use any support in the following situations: (1) when sunk costs are high enough to make expected profits negative even with if expected subsidy and tax credit are positive; (2) when expected tax credit or subsidy are too low relative to costs of using support.[20]

This discussion suggests that we should expect the following correlation patterns between the use of each type of support and appropriability and financing constraints: (1) the exclusive use of tax credits will be negatively correlated with financing constraints and positively with appropriability and previous R&D experience; (2) the exclusive use of subsidies will be highly correlated with high financing constraints and/or low appropriability; (3) the use of both tax credits and subsidies will be correlated with low financing constraints and low appropriability difficulties, and (4) the use of no support will be negatively correlated with previous R&D experience. To the extent that SMEs are more likely to face both financing and appropriability constraints than large firms, the predicted correlations are expected to be stronger in the first case.

5 Empirical analysis: variables, empirical model and results

5.1 Variables and empirical model

Our purpose is to test whether the use of each policy instrument is correlated with indicators of appropriability and financing constraints with the signs predicted in the discussion above. We use two non-overlapping waves of the PITEC to construct our variables. The dependent variables are *Tax incentives,* which is a binary variable that equals 1 if a firm declares having claimed R&D tax credits any year within the period 2006–2008, and *Direct support,* which equals 1 if the firm has obtained direct funding from the Central Administration any year within this period.[21] Only subsidies (grants) are included in this definition; loans and public contracts are excluded. Both variables are defined over a 3 years period because tax credits may be carried forward, and direct support may spread over more than 1 year.[22]

The survey does not provide information about whether a firm applied for but did not obtain direct support; consequently, observed status captures not only a firm's decision to apply but also the public agency's preferences. While knowing which firms are rejected applicants would be of interest for further

[19] In the corporate taxation literature, Keuschnigg and Ribi (2010) predict that R&D tax credits will not only encourage innovation but also relax financing constraints and help innovative firms to exploit investment opportunities to a larger extent. Edgerton (2010), however, finds that the responsiveness to investment tax incentives varies with firm cash flows. We believe that even without knowledge spillovers, SMEs and young firms that are financially constrained will be less likely to benefit from R&D tax credits. Large firms, however, can have positive taxable income from other activities, and the expected tax credit may be more predictable, helping them mitigate mild appropriability or financing constraints.

[20] In practice, some firms may perform incremental R&D that would not qualify for a subsidy, but might qualify for a tax credit. Compliance costs and fear of a tax audit may deter some of those firms from claiming tax credits. See also footnote 12.

[21] Regional or local governments do not provide R&D tax incentives. Regarding direct support, some firms may obtain additional funds from local, central or European administrations, but eligibility criteria for support may differ across government levels, so aggregation over jurisdictions might distort results (Blanes and Busom 2004). Since R&D tax incentives are a policy implemented at the Central government level, they should be compared to direct support provided by the same government level.

[22] We later test for the sensitivity of results to changes in the definition of the dependent variables, and to the use annual observations.

policy analysis, what we are interested in here is whether obtaining support and our measures of innovation barriers are correlated, which would reflect the ability of the public agency to select from the pool of applicants those firms or projects that should be supported from a social perspective. Non applicants, and rejected applicants would fail to fulfil these requirements.

Our core independent variables are constructed as follows. As a proxy for *financing constraints* (θ) we use a direct measure obtained from a survey question about the importance given by the firm to difficulties in financing innovation with internal or external funds. In the literature, cash flow has been frequently used as a proxy for financing constraints in R&D investment equations, but as this measure has been subject to criticism, some researchers have recently turned to using measures of financing constraints derived from direct questions in surveys (Gorodnichenko and Schnitzer 2013; Hajivassiliou and Savignac 2011; Hottenrott and Peters 2012).[23] Direct measures may in turn have other shortcomings, such as subjectivity and endogeneity. We address these concerns by (1) measuring the relative importance of each barrier with respect to the average importance of all barriers for that firm and testing for endogeneity of this measure; (2) using lagged indicators of barriers, (2) dropping from the sample firms that declare that there is no need to innovate as the main reason for not doing so.[24] Because of the observed high correlation between the importance of internal and external barriers, we aggregate them in a single measure, although in Sect. 6 we present separate estimates for each.

Direct measures of *appropriability* (λ) are hard to come by. In most existing empirical work either firm's belief on the effectiveness of legal protection methods, or their actual use, have been accepted as the standard indicator of outgoing spillovers (Cassiman and Veugelers 2002). We also take this approach, for lack of better alternatives, and define a binary variable which takes the value of 1 if the firm has used any (copyrights, trademarks, design or patent). There will be some ambiguity on how to interpret this variable, since firms which do not use these mechanisms may have alternative ways of appropriating revenues.[25] In order to control for some industry-level features that might affect individual appropriability we introduce the percentage of firms that believe that information from other firms in the field is an important source of ideas for own innovation projects, as well as the ratio of firms that introduce a novelty at the market level to firms that introduce novelty at the firm level, as a measure of the importance of imitation.

We take into account a set of other variables and controls since other factors condition firms' decisions regarding R&D. As a simple indicator of whether the firm faces R&D entry sunk costs (Mañez-Castillejo et al. 2009) we include two binary variables reflecting past R&D experience: whether the firm performs R&D in a continuous way, and whether it does so occasionally. As young firms may face in particular high sunk costs, we add a binary variable for firms that are 5 years of age or younger in knowledge intensive industries. We also take into account additional barriers to innovate as perceived by the firm: the existence of an established dominant firm, which may discourage other firms' R&D (Cabral and Polak 2012); the degree of demand risk, lack of personnel and lack of information; human capital, a driver of the ability of a firm to generate ideas and high quality R&D projects (Leiponen 2005; Arvanitis and Stucki, 2012). A firm's labor productivity relative to industry average is included for two reasons: recent work shows that a firm's incentives to innovate may be affected by its position relative to the technological frontier (Aghion et al. 2009); and returns to innovation may be higher for more productive firms (Aw et al. 2011). Additional control variables are included to account for other possible sources of heterogeneity: exporter status, firm

23 Hajivassiliou and Savignac (2011) use a French firm-level data set that includes subjective, direct indicators of financing constraints similar to ours as well as objective but indirect indicators such as leverage ratio, cash flow or the profit margin. They find that they are highly correlated.

24 In our sensitivity analysis, we will redefine financing constraints as a binary variable equal to 1 if the firm considers that lack of internal or external funds is of high importance. We also construct a control variable that captures the firm's overall perception of difficulties (*awareness of constraints*).

25 Secrecy may be a preferred option for some projects or firms. The survey does not include any direct question related to the firm's concern for imitation by rivals, which would provide a direct indicator of expected appropriability difficulties. Firms are only asked about the actual use of legal protection mechanisms. We assume that use of these mechanisms signals that a firm believes that threat of imitation is important and that using legal protection may prevent it at least to some extent.

size, regional location, type of industry (by knowledge intensity). All variables are defined in Table 7 in the appendix, while Table 8 provides descriptive statistics by policy use status.

Since we focus on testing whether the observed patterns of use of the policy instruments can be related to firm level indicators of market failures as discussed above, we use for our baseline specification a bivariate probit model, which implies that subsidy and tax credit participation status are two random variables that may be determined separately, although allowing for correlation between the random terms across both participation variables.[26] The empirical model is:

$$S = 1 \quad \text{if } S^* = b_s X + e_s > 0, \quad S = 0 \text{ otherwise} \tag{2}$$

$$T = 1 \quad \text{if } T^* = b_t X + e_t > 0, \quad T = 0 \text{ otherwise} \tag{3}$$

where S stands for obtaining a grant or subsidy, and T stands for claiming a tax credit. The random terms are assumed to be jointly distributed as a bivariate normal BN($\mathbf{0}$, $\mathbf{1}$, ρ); variables in X are lagged. This model generates four possible mutually exclusive situations a firm can be in: no support (0,0); uses only tax credits (0,1); uses only a direct subsidy (1,0) and uses both a grant and claims a tax credit (1,1), and therefore four sets of corresponding joint probabilities. We will report below the average of marginal effects for each observation, computed at each value of x (AME), on the joint probability.

An alternative specification consists of using a multinomial probit model (MNP) with four mutually exclusive alternatives. It imposes the assumption that each pair of subsidy and tax credit status is viewed by the firm as a distinct alternative to other pairs, and that the alternative with the highest value is chosen. We estimate this model later and report results in Sect. 6.

We separately estimate the model for SMEs and for large firms for several reasons. A thick body of research compares SMEs and large firms in several dimensions: performance, governance, innovation and R&D, access to finance are some of them. Access to finance may be difficult for SMEs because of their limited collateral, and, for those who in addition are young, by lack of reputation; sunk costs may vary across firm size, as well as the ability to appropriate returns from innovation.[27] In addition, the design of both instruments may differ across firm size as a result of the policy-makers' wish to encourage SMEs to participate in those programs.[28] Finally, different sampling procedures are used for firms with less than 200 employees and firms with 200 or more (see footnote 7).

5.2 Results: baseline estimation

Before estimating the bivariate probit model, we test for the endogeneity of the lagged financing constraints indicator with the control function approach, using firm age as the exclusion restriction. We do not reject the null of exogeneity; the results of the set of exogeneity tests are shown on Table 9. We then estimate the bivariate probit model for subsidies and tax incentives. We obtain a low but positive and significant correlation between the residuals of both equations, suggesting that some common unobserved variables affect the use of both instruments in the same direction.[29]

Tables 2, 3 and 4 report the estimated average marginal effect of a change in each explanatory variable on the joint probability of each of the four possible situations a firm may be in. We first discuss the marginal effects on the probability of using only tax credits and of using only direct support, as we expect the results of these two cases to offer a sharper picture of the potential differences between both tools than the other two.

For SMEs, being *financially constrained* reduces the probability of using only tax credits by about 5 % points (pp), while it increases the probability of using only direct support also by about 3 pp. These results are consistent with the expected patterns discussed in

[26] Dependent variables are obtained from PITEC 2008 survey, while independent variables are taken from PITEC 2005 in order to deal at least partially with potential endogeneity issues.

[27] Regarding SMEs and acess to financing for innovation, see Beck et al. (2008), Hall and Lerner (2010) and Canton et al. (2013).

[28] In the case of tax incentives, different credit rates or different caps may be applied to SMEs, as is our case.

[29] We perform several tests. We test for equality of coefficients of our core variables across the two equations in the bivariate model. The null is rejected in the case of SMEs, but not for large firms. Chi square tests not reported in the tables but are available on request. As a specification test, we perform a test for normality of residuals (Chiburis 2010).

Table 2 SMEs—Bivariate probit regression—Marginal Effects

	Both instruments	Only subsidies	Only tax credits	None
Financing constraints	0.004	0.027***	−0.053***	0.021
	(0.007)	(0.007)	(0.013)	(0.016)
IP protection	0.018***	0.004	0.021*	−0.043***
	(0.006)	(0.007)	(0.012)	(0.013)
Dominant firm	0.000	0.003	−0.006	0.003
	(0.006)	(0.006)	(0.011)	(0.013)
Demand risk	0.002	−0.005	0.014	−0.011
	(0.006)	(0.007)	(0.012)	(0.012)
Low skill emp.	−0.069***	−0.038**	−0.027	0.134***
	(0.016)	(0.017)	(0.026)	(0.031)
High skill emp.	0.064***	0.041***	0.012	−0.117***
	(0.011)	(0.012)	(0.022)	(0.024)
Considers TI	0.072***	−0.008	0.134***	−0.197***
	(0.007)	(0.006)	(0.011)	(0.012)
Stable R&D	0.094***	0.025**	0.095***	−0.213***
	(0.010)	(0.010)	(0.017)	(0.019)
Occasional R&D	0.050***	0.016	0.044**	−0.111***
	(0.011)	(0.012)	(0.019)	(0.022)
Fixed investment	0.035***	0.010	0.035**	−0.080***
	(0.009)	(0.009)	(0.016)	(0.018)
Relative productivity	0.015***	−0.007*	0.041***	−0.049***
	(0.004)	(0.004)	(0.008)	(0.009)
Group	0.018**	0.012	0.002	−0.033*
	(0.008)	(0.008)	(0.015)	(0.017)
Private domestic	0.026**	0.001	0.040*	−0.067**
	(0.013)	(0.012)	(0.022)	(0.027)
Exporter	0.014*	−0.009	0.043***	−0.049***
	(0.008)	(0.008)	(0.014)	(0.017)
Size: $x < 20$ emp.	−0.035***	0.009	−0.077***	0.103***
	(0.011)	(0.011)	(0.019)	(0.022)
Size: $20 \leq x < 50$	−0.024**	−0.007	−0.023	0.053***
	(0.009)	(0.009)	(0.017)	(0.019)
Size: $50 \leq x < 100$	−0.014	0.003	−0.029*	0.040**
	(0.009)	(0.009)	(0.017)	(0.020)
New*Hightec	0.019	0.056**	−0.095*	0.020
	(0.033)	(0.025)	(0.051)	(0.074)
New*Medhigh	0.001	−0.009	0.022	−0.014
	(0.020)	(0.020)	(0.035)	(0.042)
Tech Park	0.042**	0.013	0.040	−0.095**
	(0.021)	(0.017)	(0.035)	(0.047)
Hightec	0.038***	−0.009	0.081***	−0.109***
	(0.014)	(0.015)	(0.027)	(0.030)
Medhigh	0.021**	−0.013	0.062***	−0.069***
	(0.009)	(0.009)	(0.016)	(0.018)

Table 2 continued

	Both instruments	Only subsidies	Only tax credits	None
Medlow	0.004	−0.006	0.019	−0.018
	(0.009)	(0.009)	(0.016)	(0.018)
Support: local	0.071***	0.050***	0.003	−0.124***
	(0.007)	(0.007)	(0.012)	(0.014)
Support: EU	0.060***	0.064***	−0.048*	−0.076**
	(0.013)	(0.014)	(0.027)	(0.030)
Industry innovativeness	0.102***	0.079**	−0.011	−0.170**
	(0.032)	(0.032)	(0.058)	(0.068)
N	2,241	273	778	334

Dependent variables: S = obtaining a subsidy and T = claiming a tax credit

Each column shows estimated average marginal effects of covariates on each joint probability. The total number of observations is 3,626; log pseudolikelihood = − 3,212.04; Wald $\chi^2(58) = 1{,}064.5$; $\rho = 0.25$ (SE = 0.03). Regional binary variables have been included. The omitted firm size category is 100–199 employees

***, ** and * Significance at the 1, 5 and 10 % level, respectively

Sect. 4 above. Regarding *appropriability*, we find that SMEs that have protected IP in the preceding period are more likely to use tax incentives. This result is also consistent with the predicted pattern. The fact that high productivity and export status, along with protection, are positively correlated with the use of tax credits corroborates the hypothesis that this instrument acts as a prize for success. The probability of using only grants is found to be independent of protection status. This is a somewhat surprising result, as a negative sign could be expected. This outcome may be attributed to a number of factors, but lacking information on the nature of the aproved projects, it would be premature to extract any conclusions, beyond what the estimated coefficient says, which is that protection is unrelated to the use of grants, in contrast to tax incentives.[30]

We test for interaction effects between appropriability and financing constraints by including an interaction term in the estimated equations. We find that the effect of using protection on some of the joint probabilities varies depending on the intensity of financing constraints. In particular, the probability of using only tax incentives is higher for firms that protect than for firms that do not protect, and falls as financing constraints increase, but more so for firms that do not protect. Figure 2 shows the estimated probabilities for different values of financing constraints and each protection state. While the probability of using only tax credits if the firm protects and has a low level of financing constraints is 27 %, and falls to 22 % if financial constraints are high, when the firm does not protect, with low financing constraints the probability is 22 %, while with high constraints it falls to 14 %. This shows that protection enhances appropriability, allowing firms to generate profits so that tax credits are likely to be claimed, even with financial constraints. Protection offsets somewhat the negative effects of financing constraints.[31]

Table 2 shows as well that previous R&D experience increases the likelihood of using only tax credits by 10 pp. if the firm is a continuous performer, and by 4 pp. if it does it occasionally. The likelihood of using only grants increases only slightly with experience,

[30] One possible explantation is that past protection use is an imperfect approximation to appropriability of approved projects; a second possibility is that it may be difficult for the agency to evaluate the degree of appropriability of an R&D project, so that financing constraints carry more weight in the decision rule; it is also possible that firms do not submit proposals for R&D projects that do not reach some appropriability threshold.

[31] The inclusion of the interaction term does not affect the average marginal effect of remaining variables. An alternative way to test for interaction effects is to create a binary variable for each combination of appropriability difficulties and financing constraints. Estimation results show that relative to firms that protect and do not face important financing constraints, those that suffer from both problems are 7 pp. less likely to use tax credits only, 2 pp. more likely to use a subsidy only, and 2 pp. less likely to use both types of support.

Table 3 Large firms—Bivariate probit regression—Marginal effects

	Both instruments	Only subsidies	Only tax credits	None
Financing constraints	0.008	0.050**	−0.087**	0.029
	(0.029)	(0.021)	(0.035)	(0.038)
IP protection	0.021[a]	0.016	−0.021[a]	−0.016
	(0.020)	(0.016)	(0.027)	(0.026)
Dominant firm	−0.017	−0.015	0.021	0.011
	(0.019)	(0.016)	(0.026)	(0.025)
Demand risk	−0.006	0.016	−0.032	0.021
	(0.019)	(0.016)	(0.028)	(0.026)
Low skill emp.	−0.088*	0.021	−0.069[a]	0.136**
	(0.046)	(0.035)	(0.056)	(0.055)
High skill emp.	0.029	−0.001	0.012	−0.040
	(0.047)	(0.048)	(0.082)	(0.063)
Considers TI	0.086***	−0.065***	0.147***	−0.168***
	(0.020)	(0.014)	(0.023)	(0.024)
Stable R&D	0.243***	0.009	0.068**	−0.320***
	(0.032)	(0.019)	(0.031)	(0.034)
Occasional R&D	0.135***	0.012	0.025	−0.172***
	(0.041)	(0.026)	(0.044)	(0.049)
Fixed investment	−0.012	−0.014	0.021	0.005
	(0.040)	(0.027)	(0.046)	(0.049)
Relative productivity	0.043***	−0.008	0.030[a]	−0.064***
	(0.016)	(0.012)	(0.020)	(0.021)
Group	0.039[a]	0.013	−0.010	−0.042
	(0.025)	(0.017)	(0.028)	(0.033)
Private domestic	0.104***	0.030*	−0.018	−0.116***
	(0.023)	(0.018)	(0.030)	(0.029)
Exporter	0.032[a]	−0.003	0.016	−0.045
	(0.029)	(0.023)	(0.038)	(0.037)
Size: $200 \leq x < 400$ emp.	−0.112***	−0.053**	0.057[a]	0.109**
	(0.034)	(0.024)	(0.041)	(0.044)
Size: $400 \leq x < 700$	−0.066*	−0.064**	0.093**	0.038
	(0.036)	(0.027)	(0.046)	(0.047)
Size: $700 \leq x < 1{,}000$	−0.066	−0.033	0.037	0.062
	(0.045)	(0.032)	(0.056)	(0.058)
New*Hightec	0.045	0.176**	−0.300**	0.079
	(0.134)	(0.083)	(0.147)	(0.179)
New*Medhigh	−0.180*	0.057	−0.165	0.287**
	(0.103)	(0.096)	(0.166)	(0.138)
Tech Park	0.019	0.064[a]	−0.108[a]	0.025
	(0.063)	(0.047)	(0.082)	(0.084)
Hightec	0.029	0.004	0.003	−0.036
	(0.042)	(0.037)	(0.062)	(0.054)
Medhigh	0.076***	0.015	−0.001	−0.090***
	(0.026)	(0.019)	(0.033)	(0.033)

Table 3 continued

	Both instruments	Only subsidies	Only tax credits	None
Medlow	0.066**	0.018	−0.010	−0.074**
	(0.026)	(0.019)	(0.032)	(0.034)
Support: local	0.115***	0.049***	−0.048*	−0.116***
	(0.021)	(0.016)	(0.028)	(0.029)
Support: EU	0.090***	0.086***	−0.124***	−0.052
	(0.034)	(0.027)	(0.047)	(0.046)
Industry innovativeness	0.140[a]	0.020	0.012	−0.172[a]
	(0.096)	(0.067)	(0.115)	(0.124)
N	161	83	209	358

Dependent variables: S = obtaining a subsidy and T = claiming a tax credit

Each column shows estimated average marginal effects of covariates on each joint probability

The total number of observations is 811; log pseudolikelihood = − 796.99; Wald $\chi^2(58) = 416.9$; $\rho = 0.22$ (SE = 0.07). Regional binary variables have been included. The omitted firm size category is 1,000 or more employees

[a] Considering that our sample of about 800 firms with 200 or more employees is large relative to the total number of firms this size in the manufacturing industries—which in 2005 was of about 1,400 firms, according to the Spanish Statistical Office (DIRCE)—, it would be appropriate to use a finite population correction, which recalculates the standard errors of the estimates taking into account the size of the sample relative to the population. When using this method, we find indeed that some more variables become significant: this is indicated with the superscript a

***, ** and * Significance at the 1, 5 and 10 % level, respectively

and not at all if the firm is an occasional R&D performer. Tax credits are more thus likely to benefit stable R&D performers that do not have to incur in sunk costs. An even stronger difference across both instruments is observed with respect to young firms in high-tech industries: while the likelihood of this firms using tax credits only is almost 10 pp lower than otherwise, the likelihood that they obtain a grant is 6 pp. higher. This suggests that subsidies may induce firms, especially young and knowledge-based, to invest in R&D, while tax incentives alone are unlikely to do so.

There are some other interesting differences across both tools. A high level of human capital increases the probability of using direct support only. A firm's relative productivity is positively correlated to the probability of using tax incentives only, but negatively with the probability of receiving subsidies. Firms in the smallest size intervals (<20 employees) are less likely to use tax incentives, while they do not show any disadvantage relative to larger firms in the use of subsidies. Firms in high-tech and medium–high technological intensity are more likely to use tax incentives only, while having received support from local and European administrations increases the likelihood of obtaining subsidies, but not tax incentives. To the extent that European institutions fund projects at pre-competitive stages, and thus more likely to generate spillovers, this result would strengthen the hypothesis that subsidies can be more helpful at addressing knowledge spillovers than tax incentives.

We next 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 human capital and previous experience in R&D are among the most important determinants of using both kinds of support, along with protection. The likelihood of not using any support is higher for firms with very low levels of human capital, without previous R&D experience, low relative productivity and domestic market oriented. These last two results are in line with Takalo et al. (2012) as well as with Aw et al. (2011) in that productivity and exporting status increase the reward of R&D investments.

Table 3 shows estimation results for large firms. We find a significant, positive correlation between financing constraints and the likelihood of using subsidies only, while the correlation is negative with using tax incentives only. Magnitudes are even a little higher than for SMEs. When we distinguish between internal and external financing constraints (see Table 5 below) we find that large firms' status is highly sensitive to external but not to internal constraints. Use of IP protection is

Table 4 All firms—Bivariate probit regression—Marginal effects

	Both instruments	Only subsidies	Only tax credits	None
Financing constraints	0.007	0.030***	−0.057***	0.019
	(0.008)	(0.007)	(0.013)	(0.015)
IP protection	−0.002	−0.000	−0.002	0.004
	(0.006)	(0.006)	(0.010)	(0.011)
Dominant firm	0.003	−0.002	0.007	−0.008
	(0.006)	(0.006)	(0.011)	(0.011)
Demand risk	0.020***	0.006	0.012	−0.038***
	(0.006)	(0.006)	(0.011)	(0.012)
Low skill emp.	−0.072***	−0.027*	−0.032	0.131***
	(0.016)	(0.015)	(0.024)	(0.027)
High skill emp.	0.064***	0.029**	0.018	−0.111***
	(0.012)	(0.012)	(0.022)	(0.023)
Considers TI	0.078***	−0.018***	0.136***	−0.196***
	(0.006)	(0.006)	(0.010)	(0.011)
Stable R&D	0.119***	0.025***	0.096***	−0.239***
	(0.010)	(0.009)	(0.015)	(0.017)
Occasional R&D	0.065***	0.017	0.044**	−0.126***
	(0.012)	(0.011)	(0.018)	(0.020)
Fixed investment	0.034***	0.006	0.029*	−0.069***
	(0.010)	(0.009)	(0.015)	(0.017)
Relative productivity	0.022***	−0.003	0.035***	−0.054***
	(0.005)	(0.005)	(0.008)	(0.010)
Group	0.025***	0.016**	−0.004	−0.037**
	(0.008)	(0.007)	(0.013)	(0.015)
Private domestic	0.042***	0.015	0.020	−0.078***
	(0.011)	(0.010)	(0.017)	(0.020)
Exporter	0.019**	−0.007	0.039***	−0.051***
	(0.008)	(0.008)	(0.013)	(0.015)
Size: $x < 20$ emp.	−0.069***	−0.028*	−0.026	0.124***
	(0.017)	(0.015)	(0.028)	(0.033)
Size: $20 \leq x < 50$	−0.058***	−0.046***	0.027	0.077**
	(0.016)	(0.014)	(0.026)	(0.031)
Size: $50 \leq x < 100$	−0.048***	−0.036**	0.018	0.066**
	(0.016)	(0.014)	(0.027)	(0.032)
Size: $100 \leq x < 200$	−0.027	−0.039***	0.050*	0.015
	(0.017)	(0.015)	(0.028)	(0.033)
Size: $200 \leq x < 400$ emp.	−0.004	−0.018	0.033	−0.011
	(0.017)	(0.015)	(0.028)	(0.034)
Size: $400 \leq x < 700$	0.027	−0.019	0.074**	−0.083**
	(0.020)	(0.018)	(0.035)	(0.039)
Size: $700 \leq x < 1,000$	0.031	0.002	0.035	−0.067
	(0.027)	(0.025)	(0.046)	(0.052)
New*Hightec	0.035	0.064**	−0.094*	−0.006
	(0.037)	(0.026)	(0.052)	(0.073)

Table 4 continued

	Both instruments	Only subsidies	Only tax credits	None
New*Medhigh	−0.011	−0.015	0.018	0.007
	(0.023)	(0.020)	(0.035)	(0.042)
Tech Park	0.042**	0.022	0.006	−0.071*
	(0.021)	(0.016)	(0.033)	(0.042)
Hightec	0.037**	−0.009	0.065***	−0.093***
	(0.014)	(0.014)	(0.025)	(0.027)
Medhigh	0.031***	−0.006	0.052***	−0.077***
	(0.009)	(0.008)	(0.014)	(0.016)
Medlow	0.013	0.001	0.015	−0.028*
	(0.009)	(0.008)	(0.014)	(0.016)
Support: local	0.082***	0.050***	−0.005	−0.127***
	(0.007)	(0.006)	(0.011)	(0.012)
Support: EU	0.066***	0.071***	−0.071***	−0.067***
	(0.012)	(0.012)	(0.024)	(0.025)
Industry innovativeness	0.107***	0.068**	−0.012	−0.163***
	(0.032)	(0.029)	(0.051)	(0.060)
N	494	346	981	2,601

Dependent variables: S = obtaining a subsidy and T = claiming a tax credit

Each column shows estimated average marginal effects of covariates on each joint probability

The total number of observations is 4,402; log pseudolikelihood = − 3,926.39; Wald $\chi^2(66)$ = 1,477.18; ρ = 0.25 (SE = 0.03). Regional binary variables have been included. The omitted firm size category is 1,000 or more employees

***, ** and * Significance at the 1, 5 and 10 % level, respectively

basically unrelated to the use of these instruments. The most distinctive differences between firms that use only tax incentives and firms that use only subsidies are the role of human capital, whose importance is now smaller, except for the probability of using none of the instruments, and export status. We also find that firms that have previous R&D experience are more likely to use tax incentives only, or both forms of support, but experience is not correlated to the probability of using subsidies only. Young firms in knowledge intensive industries are also more likely to rely on subsidies rather than in tax incentives, in line with the result obtained for SMEs. When possible interactions are taken into account, we find that firms that protection does not affect the correlation between the likelihood of using only one instrument and the intensity of financing constraints.

Table 4 shows the results for the whole sample, merging both firm-size groups. We find that the estimates corresponding to the importance of financing constraints are significant and have the same sign as in the two separate subsamples. But estimates for protection are not significant now, and the different importance of human capital for SMEs and large firms is concealed.

To sum up, our results suggest that tax credits are less likely than subsidies to benefit firms that face financing constraints.[32] Direct support and tax incentives would therefore not be substitutes for addressing them.[33] The ability to protect IP helps SMEs to benefit from tax credits, but not large firms. Tax incentives might provide some compensation to financially unconstrained firms that are affected by at most mild appropriability difficulties.

[32] Our results differ from Gelabert et al. (2009) with respect to the relationship between financing constraints and the likelihood of using subsidies. This might be partly explained by differences in sample composition, as theirs consists of firms that reported positive internal R&D expenditure at least one of these years in all sectors, and average firm size is large.

[33] In particular, our finding that financially constrained SMEs are less likely to use tax credits is in line with Edgerton 2010.

6 Robustness analysis

In this section we explore the robustness of our results to the following changes (1) different subsamples of firms; (2) alternative definition of financing constraints; (3) alternative definitions of the dependent variables, and (4) use of a different econometric model.

We begin by re-estimating the baseline model for three different subsamples of firms. The first subsample includes only firms that had introduced products new to the market in 2005 or before, because this particular subset may be more sensitive to appropriability issues; second, we restrict the sample to firms that were doing R&D in 2005, and finally we estimate the model for firms in high tech and medium tech manufacturing sectors.[34] Second, we change the way we calculate financing constraints; we first distinguish between internal and external constraints; and second, instead of computing the relative importance of each particular constraint for the firm, we generate a binary variable for each barrier which equals 1 when the barrier is of high importance to the firm, and include an index of overall barriers. Third, we change the definition of dependent variables: instead of both referring to the 2006–2008 period, we use the status observed in 2007/8. As a further test we re-estimate the model using an alternative variable on public support available in the survey which includes not only grants but other types of support, such as public loans. We finally estimate a multivariate probit model, where each one of the four alternatives regarding policy use is a random variable and the choice of an alternative involves an explicit comparison with the other three.

Table 5 reports estimated average marginal effects for the core independent variables of interest, financing constraints and IP protection, obtained using the different specifications.[35] The estimates remain stable for SMEs: financing constraints are always negatively correlated to the use of tax incentives only, while they increase the likelihood of using direct support only. As for appropriability, firms that have used legal protection methods are more likely to use tax incentives, whether alone or in combination with subsidies. The estimates obtained when using a different period, different variables for direct support, or for financing constraints, and the multivariate probit model are all very similar. For the sample of large firms, results for financing constraints are mostly robust to changes in the computation of variables or to estimation model. The main additional insight from this exercise is that it is difficulties in external funding, rather than lack of internal resources, that are correlated with the use of each instrument. Appropriability becomes a significant variable when using as dependent variable for direct support a variable that includes both public grants and loans, suggesting that it is likely that the agency's requirements for these two types of direct support differ.

6.1 Some further results: change of support status

While the data does not allow us to estimate a dynamic model, we can complement our analysis by testing whether changes in support status across the two periods are related to appropriability, financing constraints and previous R&D experience. Table 6 below reports the proportion of firms by support status in 2005 and their status in period 2006–2008. It shows that about 20–25 % of those firms were not using any support in 2005 did obtain some during the next period. Most often they obtained a subsidy in the case of large firms. There is a higher stability in using both instruments across periods among large firms.

We define support status in 2006–2008 as a discrete dependent variable with four possible values: 0 (no support), 1 (only subsidy), 2 (only tax incentives) and 3 (both) and use a multinomial logit model to estimate the probability of transition of firm i from the state 0 (no support) to the state j' next period. This probability is given by:

$$\mathrm{Prob}(S_{it} = j' \,|S_{it-1} = 0) = (\exp(x_{it-1}\beta))/\left(\sum_j \exp(x_{it-1}\beta)\right)$$

where $i = 1,\ldots N$, and $j' = 0, 1, 2, 3$; the vector of independent variables is the same as in the previous section. We estimate these probabilities only for SMEs, as the number of large firms in each cell becomes too small. We find that the probability of switching from no support to using only subsidies in

[34] We also check whether changing the definition of SMEs from those with <200 employees to those with <250 and turnover less than €50 million, in line with the standard Eurostat definition, changes results. It does not. Results are available upon request.

[35] Remaining variables as in the baseline. Detailed results are available on request.

Table 5 Robustness analysis—Average marginal effect of financing constraints and appropriability on the likelihood of support status

Type of support	Financially constrained				Protect			
	None	TC	S	TC + S	None	TC	S	TC + S
Panel A: SMEs								
Baseline		−.05	.03		−.04	.02		.02
1. Dep var as in baseline,		−.06	.04					
Subsample of firms that introduced								
Products new to the market in 2003–2005								
2. Dep. var. as in baseline,		−.05	.03					
Subsample of firms that did R&D in 2005								
3. Dep. var. as in baseline		−.07	.03					
Subsample of firms in high and medium–high tech industries								
4. Dep. var. as in baseline	.04	−.04	.02	−.02	−.04	.02		.02
Internal financing constraints		−.03	.01		−.04	.02		.02
External financing constraints		−.05	.03		−.04	.02		.02
Change in computation of financing constraints: binary indicators								
5. Change in dependent variables:		−.05	.03		−.05	.03		.02
Subsidy and TI in 2007/8, whole sample								
6. Change in dependent variables:		−.05	.03		−.04	.02		.02
Subsidies + loans and TI 2006–2008								
7. Multinomial probit estimation		−.06	.02			.03		.02
Whole sample, variables as in baseline								
Panel B: large firms								
Baseline		−.08	.05					
2. Dep. var. as in baseline		−.11	.07					
Subsample of firms that did R&D in 2005								
3. Dep. var. as in baseline		−.12	.07					
Subsample of firms in high and med–high tech industries								
4. Dep var. as in baseline		−.05	.03					
External financing constraints		−.09	.05					
Change in computation of financing const: binary indicator (for external constraints)								
5. Change in dependent variables:		−.08	.04					
Subsidies + loans and TI 2007/8								
6. Change in dependent variables:		−.08	.06			−.05	.04	.05
Subsidies and loans, and TI 2006–2008								
7. Multinomial probit estimation		−.07	.06					
Whole sample; variables as in baseline								

Only significant estimates are reported; blank cells indicate a non-significant estimate has been obtained. For large firms estimation with the subsample of firms introducing new products could not be performed because the number of observations in some of the categories was too small (< 45 firms)

Table 6 Frequency of change of support status

Support status in 2005	Support status 2006–2008 (in %)											
	SMEs						Large firms					
	None	S	TC	S + TC	Total	*N* firms	None	S	TC	S + TC	Total	*N* firms
None	81	7	8	3	100	2678	77	11	8	4	100	462
S	35	43	5	17	100	189	16	61	8	16	100	51
TC	6	1	74	19	100	712	2	0	65	32	100	245
S + TC	2	4	18	76	100	115	0	0	11	89	100	62

None = no subsidy, no tax credit; S = subsidy, no tax credit; TC = No subsidy, tax credit, S + TC = subsidy and tax credit

the next period increases by 2 pp. with financing constraints and firms using IP protection, but by 8 pp. for firms with high human capital. The probability of switching from no support to using only tax incentives is positively correlated with using IP protection, being a stable investor in R&D, and having a high relative productivity. These results are mostly in line with the baseline reslts for SMEs.

7 Conclusions and implications

R&D policies are expected to address certain market failures and lead to increased private R&D effort. Previous empirical research has studied the effects of support on recipient firms in order to test for crowding out effects, using the concept of additionality. However, this approach is a necessary step to evaluate the impact of R&D subsidies or R&D tax credits, it does not answer the question of whether these instruments reach firms that face those specific types of constraints that lead to R&D underinvestment. We compare the use by SMEs and large firms of these two tools, to test directly their correlation with two potential barriers to innovation, financing constraints and appropriability, and with R&D entry costs. To the best of our knowledge this is the first time that this policy question is explicitly addressed and that both policy instruments are compared.

Using data from two waves of the Spanish CIS survey, 2003–2005 and 2006–2008, we find, for SMEs, a clear association between specific sources of market failure and the type of support used. For each instrument the sign of this relationship is the opposite: the probability of using tax incentives falls as financing constraints (whether internal or external) increase, while the likelihood of using direct funding increases. Regarding the association with appropriability, SMEs that are able to protect their innovations are more likely to use tax incentives, even if financing constraints increase.

For large firms we find that difficulties in external access to funds are positively correlated with the use of subsidies, and negatively to the use of tax credits. We do not find appropriability to be related to the use of exclusively one of the policy tools; but previous R&D experience is highly correlated with using both tools or tax incentives only.[36] What is common to both large firms and SMEs is that they both are more likely to use tax incentives (alone or along with subsidies) when they have previous R&D experience, and that young firms in knowledge intensive industries are less likely to use tax incentives than subsidies. This suggests that direct support may induce non-R&D doers and young firms to invest in R&D, while tax credits are unlikely to do so.

These findings have some policy implications. First, R&D tax incentives and R&D subsidies do not appear to be equivalent tools for SMEs. Our evidence supports the hypothesis that tax incentives provide a reward to firms that do not face important financing constraints and whose projects enjoy high appropriability, while they are likely to leave out projects that should be supported. Tax incentives, nevertheless, might be potentially useful in addressing mild appropriability difficulties of firms that are not financially constrained. In that sense, direct support and tax incentives could be complementary for a particular

[36] To the extent that large firms have lower appropriability and internal financing difficulties; there might be more room for some crowding out as found by Lokshin and Mohnen (2012).

subset of firms or projects.[37] Second, our results imply that one size may not fit all in innovation policy, as the type of market failure faced by firms differs across firm size. And third, both for large firms and SMEs, R&D subsidies are more likely to reach firms that do not have previous R&D activity or are young and knowledge intensive. Direct support might be more appropriate than tax credits when the main policy goal is to increase the number of firms that perform R&D (an effect on extensive margin). Tax credits may instead help R&D performers to continue or increase the intensity of this activity (an effect on the intensive margin).

Our work also illustrates that innovation policy analysis could be improved if surveys provided enhanced indicators of some constraints, particularly of the fear or risk of imitation as a potential barrier to innovate. As the design and administration of innovation surveys is spreading across countries, revising or introducing some questions in light of existing results may have a significant payoff.

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Appendix A: Main features of R&D tax incentives and direct support in Spain

Tax incentives

R&D Tax incentives for R&D investment have been in place in Spain since the early eighties, but the major legal change dates from 1995, when a new law on corporate taxation was introduced. The definition of R&D eligible expenses follows the OECD Frascati Manual guidelines. Tax incentives are basically provided through deductions from corporate taxable income (100 % of current R&D expenditures, and 100 % write off of R&D fixed assets except buildings) and from the firm's tax liability (the tax credit). The tax credit offered is a hybrid of an incremental and a volume based system. In 1999 (Act 55/99) non-RD technological innovation expenditures were included as eligible for tax credit at a 10 or 15 % rate, depending on the type of expenditure. Tax credit rates were initially 20 % of R&D volume, and 40 % of the excess on average R&D expenditures of the two preceding years, with a cap of 35 % of the tax liability. In 2001 (Act 24(01)) both rates were increased (to 30 and 50 % respectively), as well as the cap (to 50 % for SMEs if the credit was greater than 10 % of the tax liability). In 2004, in addition, firms could deduct 20 % of the labour cost of employees assigned exclusively to R&D tasks. Rates were somewhat reduced in 2007 and 2008. From 2007 onwards, firms could use the alternative option of deducting from the social security tax 40 % of the liability corresponding to R&D employees. Excess credit can be carried forward up to 15 years. Firms that obtain R&D and innovation subsidies can claim tax credits on all R&D expenditure remaining after subtracting 65 % of the subsidies received.

Direct support to R&D and innovation through CDTI

The annual reports of the main funding agency, CDTI, provide the following information about direct support during the period 2006–2008. In 2006, CDTI contributed 802 million € to 1032 projects, out of 1434 applications. Most of the funding (50 %) was allocated to technological development projects; 14 % to technological innovation projects (mostly adoption of innovations); 9 % to cooperative industrial research, 25 % to large public–private research consortia (CENIT projects). The first three types offered 0-interest loans and up to a 20 % grant, depending on the features of the project. CENIT projects were offered grants of up to 50 % of the R&D budget; these are 4 year-long projects, with budgets between 20 to 40 million €. Loans were offered to new technology based firms of up to 70 % of the budget of the project, with maximum funding of 400 thousand € (Neotec Projects). In 2007, CDTI contributed 1,090 million €

[37] The use of multiple policy instruments to address private underinvestment in R&D may be optimal in a second-best world with multiple market failures, coupled with informational, political and administrative capacity constraints. These issues have been considered in the design and implementation of environmental policies (Bennear and Stavins 2007), and may be relevant for innovation policy as well.

to 1,111 projects. In 2008, projects i) and ii) were combined in a single category so as to comply with EU state aid rules. Total CDTI funding decreased to 766 million € that were allocated to 1,124 projects. The grant rate was increased to 25 %. CDTI also provides advice about using tax incentives to firms that obtain direct support. *Sources*: Dirección General de Tributos and CDTI's annual reports, several years.

Appendix B

See Tables 7, 8, 9 and Fig. 2

Table 7 Definition of independent and control variables

Financing constraints Dominant firm Demand risk	For each of these perceived innovation barriers, we compute the ratio between the rating given by the firm to that particular barrier and the average rating of all barriers declared by the firm
Awareness of constraints	An index of a firm's global perception of barriers to innovation. Computed by adding the rankings given by the firm to each barrier, and rescaling it so that it takes values in a 0 to 1 range; larger values indicate that a firm perceives a high overall level of barriers
IP protect	Binary variable equal to 1 if the firm has used any legal intellectual property protection mechanisms (copyrights, trademarks, design or patent)
Relative productivity (log of)	A measure of productivity distance of the firm relative to the mean of its sector of activity. Manufacturing is classified into 30 subsectors, and for each we compute the average labour productivity as sales per employee. Each firm's labor productivity in 2005 is divided by the average of its subsector
Low skill employees	Binary variable equal to 1 if firm has no employees with a higher education degree
High skill employees	Binary variable equal to 1 if firm more than 40 % of employees have higher education
Medium skill employees	Binary variable equal to 1 if firm has a positive share of employees with higher education but below 40 %
Fixed investment	Binary variable equal to 1 if the firm invested in physical capital in 2005, as a proxy for demand expectations
Considers TI	Binary variable equal to 1 if firm takes into account potential tax credit when making R&D decisions
Group membership	Binary variable; 1 if firm belongs to a group
Private domestic ownership	Binary variable; 1 if firm's ownership is private and domestic
Exporter	Binary variable; 1 if firm exports
Stable R&D	Binary variable; 1 if firm reported being continuously engaged in R&D
Occasional R&D	Binary variable; 1 if firm reported being occasionally engaged in R&D
Firm size	Four binary variables are defined for each size intervals defined according to the number of employees as follows. For SMEs: <20; between 21 and 50; between 51 and 100 and between 101 and 199. For large firms, the size intervals are: between 200 and 400; between 401 and 700; between 701 and 1,000, and more than 1,000
New firm	Binary variable equal to 1 if firm was created after year 2000
Tech park	Binary equal to 1 if firm is located in a technological park
Regional location	Three dummy variables for location in the following regions are defined: Madrid, Catalonia, Andalusia
Industry dummies	Four dummy variables are defined following the OECD classification of manufacturing industries in four groups according to technological intensity: high tech, medium–high tech, medium–low tech, and low tech
Support: local	Binary variable; 1 if firm received support from local government in the period 2003–2005
Support: regional	Binary variable; 1 if firm received support from European Union in the period 2003–2005
Industry innovativeness	Ratio of the number of firms introducing innovations new to the market relative to the number of firms introducing innovations new only to the firm at the industry level (26 industries)

Table 8 Sample descriptive statistics by support and size

Variable	No support		Only subsidies		Only tax incentives		Both	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SMEs								
Financing constraints	1.24	0.46	1.34	0.49	1.17	0.42	1.249	0.47
Dominant firm	1.15	0.53	1.14	0.48	1.17	0.51	1.225	0.55
Demand risk	1.18	0.51	1.16	0.51	1.21	0.50	1.18	0.45
Employees with higher education (%)	15.32	16.25	30.25	25.47	20.02	16.65	27.71	20.49
Low skill emp.	0.16	0.36	0.02	0.15	0.04	0.19	0.02	0.12
High skill emp.	0.04	0.20	0.19	0.40	0.08	0.27	0.18	0.39
IP protection	0.30	0.46	0.44	0.50	0.44	0.50	0.48	0.50
Awareness of constraints	0.51	0.23	0.52	0.22	0.50	0.21	0.52	0.21
Stable R&D	0.43	0.50	0.69	0.46	0.70	0.46	0.82	0.38
Occasional R&D	0.25	0.44	0.22	0.41	0.19	0.39	0.13	0.34
New*High	0.01	0.08	0.03	0.18	0.00	0.04	0.03	0.18
New*Medhigh	0.02	0.14	0.03	0.16	0.03	0.17	0.04	0.19
Tech Park	0.01	0.11	0.04	0.19	0.02	0.14	0.09	0.28
Fixed investment[a]	0.75	0.43	0.86	0.34	0.87	0.34	0.92	0.27
Relative productivity (log)[a]	−0.40	0.78	−0.47	1.356	−0.12	0.67	−0.17	0.71
Group	0.20	0.40	0.26	0.44	0.29	0.46	0.35	0.48
Private domestic	0.93	0.26	0.95	0.23	0.93	0.26	0.90	0.30
Exporter[a]	0.66	0.48	0.70	0.46	0.82	0.39	0.83	0.37
Size: $x < 20$ emp.	0.29	0.45	0.33	0.47	0.17	0.37	0.17	0.38
Size: $20 \leq x < 50$	0.34	0.47	0.29	0.46	0.35	0.48	0.28	0.45
Size: $50 \leq x < 100$	0.22	0.41	0.23	0.42	0.26	0.44	0.27	0.45
Size: $100 \leq x < 200$	0.13	0.33	0.13	0.34	0.20	0.40	0.25	0.43
Hightec	0.07	0.25	0.16	0.37	0.12	0.32	0.22	0.41
Medhigh	0.30	0.46	0.32	0.47	0.40	0.49	0.41	0.49
Medlow	0.29	0.45	0.23	0.42	0.24	0.43	0.19	0.39
Lowtec	0.21	0.40	0.15	0.36	0.14	0.35	0.09	0.29
Support: local	0.25	0.43	0.59	0.49	0.35	0.48	0.57	0.50
Support: EU	0.03	0.16	0.10	0.30	0.03	0.17	0.11	0.31
Industry innovativenes	0.45	0.12	0.50	0.12	0.48	0.13	0.51	0.14
LARGE								
Financing constraints	1.14	0.35	1.25	0.42	1.11	0.32	1.17	0.42
Dominant firm	1.17	0.55	1.15	0.48	1.21	0.57	1.08	0.41
Demand risk	1.14	0.47	1.18	0.48	1.17	0.48	1.18	0.45
Employees with higher education (%)	9.69	12.20	17.22	16.57	14.34	14.19	15.83	15.49
Low skill emp.	0.20	0.40	0.06	0.24	0.04	0.20	0.01	0.08
High skill emp.	0.01	0.12	0.05	0.22	0.04	0.20	0.04	0.19
IP protection	0.27	0.44	0.54	0.50	0.41	0.49	0.52	0.50
Awareness of constraints	0.39	0.25	0.49	0.25	0.44	0.20	0.46	0.21
Stable R&D	0.35	0.48	0.80	0.41	0.74	0.44	0.89	0.32
Occasional R&D	0.11	0.32	0.12	0.33	0.11	0.31	0.07	0.25
New*High	0.00	0.05	0.02	0.15	0.00	0.00	0.01	0.11
New*Medhigh	0.01	0.09	0.01	0.11	0.00	0.07	0.00	0.00

Table 8 continued

Variable	No support		Only subsidies		Only tax incentives		Both	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Tech Park	0.01	0.11	0.06	0.24	0.01	0.10	0.04	0.19
Fixed investment[a]	0.89	0.31	0.94	0.24	0.94	0.24	0.94	0.23
Relative productivity (log)	−0.16	0.72	−0.07	0.60	0.06	0.62	0.04	0.64
Group	0.69	0.46	0.86	0.35	0.80	0.40	0.76	0.43
Private domestic	0.64	0.48	0.71	0.46	0.62	0.49	0.77	0.42
Exporter[a]	0.80	0.40	0.87	0.34	0.88	0.33	0.90	0.30
Size: $200 \leq x < 400$ emp.	0.67	0.47	0.47	0.50	0.56	0.50	0.50	0.50
Size: $400 \leq x < 700$	0.18	0.39	0.25	0.44	0.28	0.45	0.25	0.43
Size: $700 \leq x < 1{,}000$	0.07	0.25	0.11	0.31	0.09	0.28	0.08	0.27
Size: $x \geq 1{,}000$	0.08	0.27	0.17	0.38	0.07	0.26	0.17	0.38
Hightec	0.05	0.21	0.20	0.41	0.14	0.35	0.12	0.33
Medhigh	0.25	0.44	0.30	0.46	0.31	0.46	0.41	0.49
Medlow	0.28	0.45	0.28	0.45	0.25	0.44	0.26	0.44
Lowtec	0.20	0.40	0.08	0.28	0.13	0.34	0.04	0.20
Support: local	0.16	0.36	0.48	0.50	0.23	0.42	0.56	0.50
Support: EU	0.03	0.18	0.23	0.42	0.04	0.20	0.16	0.37
Industry innovativenes	0.42	0.12	0.50	0.17	0.46	0.12	0.48	0.15

Descriptive statistics correspond to the final sample used for estimation after deleting observations with some missing value. Variables marked [a] refer to year 2005; otherwise they refer to the period 2003–2005. The share of highly educated employees refers to 2006, the first year this variable becomes available

Table 9 Exogeneity of financing constraints

	Blundell–Smith				Rivers–Vuong			
	Subsidies		Tax incentives		Subsidies		Tax incentives	
	χ^2	*P* value	χ^2	*P* value	Coeff (SE)	*P* value	Coeff (SE)	*P* value
SMEs	.65	.42	.31	.57	−.69 (.86)	.42	−.43 (.78)	.58
Large	.14	.70	.21	.64	−1.5 (4.0)	.69	1.7 (3.9)	.66
All firms	1.98	.16	.001	.97	−1.24 (.90)	.17	−.03 (.82)	.97

We test for endogeneity of financing constraints using two procedures: the Blundell–Smith test as implemented in Stata through the command "probexog", and the Rivers–Vuong test. We perform them for each of our dependent variables separately. Following BS, since the financing constraints are a continuous variable but claiming a tax credit (or obtaining a subsidy) is binary, the suspected endogenous variable is expressed as a linear projection of a set of instruments, and the residuals from the first-stage regression are added to a probit model for the binary variables. The instruments used are firm age and being a subsidiary of an American firm. Similarly the Rivers–Vuong test involves regressing the suspect variable on all independent variables and the instruments, and then including both the observed, potentially endogenous variable and the residuals in a probit regression. Under the null hypothesis, these residuals should have no explanatory power

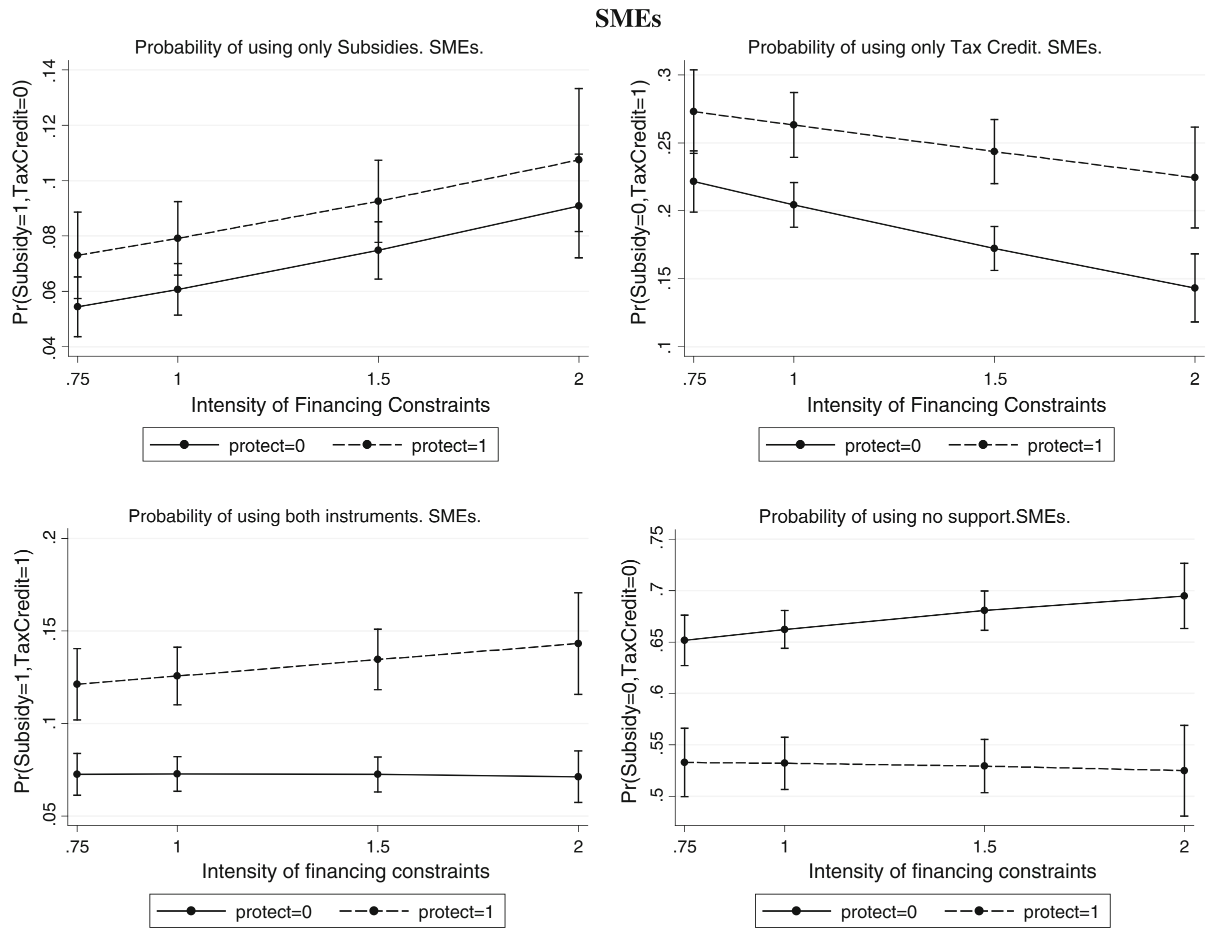

Fig. 2 Interaction effects between appropriability and financing constraints for SMEs

References

Aghion, P., Blundell, R., Griffith, R., Howitt, P., & Prantl, S. (2009). The effects of entry on incumbent innovation and productivity. *The Review of Economics and Statistics, 91*(1), 20–32.

Arqué, P., & Mohnen, P. (2012). Sunk costs, extensive R&D subsidies and permanent inducement effects. UNU-Merit working paper #2012-029.

Arvanitis, S., & Stucki, T. (2012). What determines the innovation capability of firm founders?. *Industrial and Corporate Change*, 21(4), 1049–1084.

Aw, B. Y., Roberts, M., & Xu, D. Y. (2011). R&D investment, exporting and productivity dynamics. *American Economic Review, 101*, 1312–1344.

Beck, T., Demirguc-Kunt, A., Laeven, L., & Levine, R. (2008). Finance, firm size and growth. *Journal of Money, Credit and Banking, 40*(7), 1379–1405.

Bennear, L. S., & Stavins, R. N. (2007). Second-best theory and the use of multiple policy instruments. *Environmental & Resource Economics, 37*, 111–129.

Berubé, C., & Mohnen, P. (2009). Are firms that received R&D subsidies more innovative? *Canadian Journal of Economics, 42*(1), 206–225.

Blanes, J. V., & Busom, I. (2004). Who participates in R&D subsidy programs? The case of Spanish manufacturing firms. *Research Policy, 33*, 1459–1476.

Cabral, L., & Polak, B. (2012). Standing on the soulders of babies: Dominant firms and incentives to innovate. NYU working paper EC-12-18 (forthcoming in *Journal of Industrial Economics*).

Canton, E., Grilo, I., Monteagudo, J., & van der Zwan, P. (2013). Perceived credit constraints in the European Union. *Small Business Economics, 41*, 701–715.

Cassiman, B., & Veugelers, R. (2002). R&D cooperation and spillovers: Some empirical evidence from Belgium. *American Economic Review, 92*(4), 1169–1184.

Chiburis, R. (2010). Score tests of normality in bivariate probit models: Comment. U. Texas at Austin, mimeo.

Corchuelo, B., & Martínez-Ros, E. (2010). Who benefits from R&D tax policy? *Cuadernos de Economia y Direccion de Empresa, 13*, 145–170.

Czarnitzki, D., Hanel, P., & Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconometric study on Canadian firms. *Research Policy, 40*, 217–229.

Dirección General de Tributos. (2012). Recaudación y Estadísticas del Sistema Tributario Español 1999–2009. http://www.minhap.gob.es. Accessed March 2012.

Edgerton, J. (2010). Investment incentives and corporate tax asymmetries. *Journal of Public Economics, 94*, 936–952.

Foreman-Peck, J. (2012). Effectiveness and efficiency of SME innovation policy. *Small Business Economics, 81*(1).

Fu, Q., Lu, J., & Lu, Y. (2012). Incentivizing R&D: Prize or subsidies? *International Journal of Industrial Organization, 30*(1), 67–79.

Gelabert, L., Fosfuri, A., & Tribó, J. A. (2009). Does the effect of public support depend on the degree of appropriability? *The Journal of Industrial Economics, LVII*(4), 736–767.

González, X., Jaumandreu, J., & Pazó, X. (2005). Barriers to innovation and subsidy effectiveness. *Rand Journal of Economics, 36*(4), 930–950.

Gorodnichenko, Y., & Schnitzer, M. (2013). Financial constraints and innovation: Why poor countries don't catch up. *Journal of the European Economic Association, 11*, 1115–1152.

Haegeland, T., & Moen, J. (2007). The relationship between the Norwegian R&D tax credit scheme and other innovation policy instruments. Reports 2007/45, Statistics Norway.

Hajivassiliou, V., & Savignac, F. (2011). Novel approaches to coherency conditions in LDV models with an application to interactions between financing constraints and a firm's decision and ability to innovate", mimeo. Previous version 2008, financing constraints and a firm's decision and ability to innovate: Establishing direct and reverse effects, Banque de France Discussion Paper 202, and LSE DP 594.

Hall, B., & Lerner, J. (2010) The financing of R&D and innovation, chapter 14. In B. Hall, & N. Rosenberg (Eds.), *Handbook of the economics of innovation*. Elsevier.

Hall, B., Mairesse, J. & Mohnen, P. (2010). "Measuring the returns to R&D", chapter 24. In B. Hall, & N. Rosenberg (Eds.), *Handbook of the economics of innovation*. Elsevier.

Hottenrott, H., & Peters, B. (2012). Innovative capability and financing constraints for innovation: More money, more innovation? *Review of Economics and Statistics, 94*(4), 1126–1142.

Huergo, E., & Trenado, M. (2010). The application for and the awarding of low-interest credits to finance R&D projects. *Review of Industrial Organization, 37*(3), 237–259.

Hussinger, K. (2008). R&D and subsidies at the firm level: An application of parametric and semiparametric two-step selection models. *Journal of Applied Econometrics, 23*, 729–747.

Keuschnigg, C., & Ribi, E. (2010). Profit taxation, innovation and the financing of heterogeneous firms. University of St. Gallen Department of Economics working paper series 2010 2010–01, Department of Economics, University of St. Gallen, and C.E.P.R. DP 7626.

Kobayashi, Y. (2014). Effect of R&D tax credits for SMEs in Japan: A microeconometric analysis focused on liquidity constraints. *Small Business Economics*, 42(2), 311–327.

Leiponen, A. (2005). Skills and innovation. *International Journal of Industrial Organization, 23*, 303–323.

Lokshin, B., & Mohnen, P. (2012). How effective are level-based R&D tax credits? Evidence from the Netherlands. *Applied Economics, 44*(12), 1527–1538.

Long, B. (2004). The impact of federal tax credits for higher education expenses. In C. M. Hoxby (Ed.), *College choices: The economics of which college, when college, and how to pay for it*. Chicago: University of Chicago Press.

Mairesse, J., & Mohnen, P. (2010). Using innovation surveys for econometric analysis", chapter 26. In B. Hall, & N. Rosenberg (Eds.), *Handbook of the economics of innovation*. North Holland.

Mañez-Castillejo, J. A., Rochina-Barrachina, M. E., Sanchis-Llopis, A., & Sanchis-Llopis, J. (2009). The role of sunk costs in the decision to invest in R&D. *Journal of Industrial Economics, 57*(4), 712–735.

Marra, M. A. (2008). Efecto de los incentivos fiscales y subvenciones públicas a la inversión en I + D+i de las empresas manufactureras españolas. *Hacienda Pública Española/Revista de Economía Pública, 184*, 35–66.

Meuleman, M., & De Maeseneire, W. (2012). Do R&D subsidies affect SME's access to external financing? *Research Policy, 41*, 580–591.

OCDE. (2011a). Science, technology and industry scoreboard 2011. © OECD.

OECD. (2010). The innovation policy mix", chapter 4. In STI Outlook 2010, © OECD 2010.

OECD. (2011b). Testimony by the OECD, US Senate Committee on Finance, September 2011.

Takalo, T., & Tanayama, T. (2010). Adverse selection and financing of innovation: Is there a need for R&D subsidies? *Journal of Technology Transfer, 35*, 16–41.

Takalo, T., Tanayama, T., & Toivanen, O. (2013). Estimating the benefits of targeted R&D subsidies. *Review of Economics and Statistics* 95(1), 255–272.

Wright, B. D. (1983). The economics of invention incentives: Patents, prizes and research contracts. *American Economic Review, 73*(4), 691–707.