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Assessment of the public tools used to promote R&D investment in Spanish SMEs

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Abstract In this paper, we identify the potential determinants of firm R&D to understand the effectiveness of public policies. Our results suggest a considerably low impact of tax credits and public grants on the R&D investment of the Spanish manufacturing firms. Tax credits are mainly considered by large firms that use them as a reduction in the tax burden in the corporate tax, while SMEs use public grants to alleviate financial constraints. This evidence leads to discuss alternatives to the current design of the public policies analyzed.

Keywords R&D · Tax credits · Public grants · Effectiveness · Panel data

JEL Classifications C26 · H32 · O38 · L26 · L60

1 Introduction

A key challenge facing the innovation policies nowadays is to raise the level of R&D investment in the economy. As a result governments have been increasingly allocating a wide range of public instruments in R&D such as public grants and tax credits, the two of the main policy tools applied by governments. This is the case of Spain that is part of the group of countries such as the UK, France or the USA which use both instruments (OECD 2001). Despite the increasing volume of public resources destined for this end, the position of Spain in science and technology is far from the most developed countries.[1] In 2010, expenditure on R&D in Spain in terms of GDP was 1.39 %, below the EU-27 average of 1.97 % and well below the 2.25 % in France, the 2.82 % in Germany or the 3.88 % in Finland. Given this context, Spain provides an interesting case to revisit the effectiveness of public R&D policies.

There is a growing concern about the role that public support plays in private R&D decisions. One strain of R&D literature focuses on the impact of government R&D subsidies (see surveys by David et al. 2000; Cerulli 2010; Zúnica-Vicente and Alonso-Borrego 2012). Another set of empirical studies explores the effect of fiscal incentives on private R&D investment (see Czarnitzki and Lopes-Bento 2012; Baghana and Mohnen 2009; Harris et al. 2009).

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[1] Spain has failed to improve its relative position and remains in the group of the *moderate innovators* according to the EU Innovation Scoreboard (EU 2012). EU Scoreboard data show investment in R&D by the top 1,000 EU companies and places Spain 19th of 27 EU countries in terms of innovation performance.

The usual evaluation consists in testing whether there is R&D additionality, in the sense that private firms increase their R&D expenditures by more than its costs in terms of fiscal spending. If subsidized firms increase their level of R&D investment, then public resources complement private funds, and the public policy under evaluation has "input additionality effects."[2] Despite the increasing volume of literature on this issue, the results display considerable variation across countries and over time. This explains why the effectiveness of public R&D support continues to be the object of an intense debate among economists.

Evidence of the effectiveness of public grants and tax credits referred to Spain is still very scarce and results are not conclusive. Regarding to public grants, papers by Herrera and Heijs (2007) and González and Pazó (2008) show additionality effects. In Busom (2000), full crowding-out effects cannot be ruled out. On the contrary, other authors show partial crowding-out effects although their results differ according to firm size (Marra 2006) and other characteristics like the degree of appropiability of the innovations (Gelabert et al. 2009). Regarding to tax credit, evidence shows positive but limited additional effect that seems to be more favorable for large firms (Romero-Jordán and Sanz-Sanz 2007; Corchuelo and Martínez-Ros 2010).[3]

There are further interesting issues that would also be worth exploring. One of them is the interaction between public grants and tax incentives and their effect in the R&D investment decisions (see Guellec and Van Pottelsberghe 1999, 2003). This can be particularly important given that not all such effects can flow in the same direction (David et al. 2000). Some recent assessments have started to include both policy instruments in single empirical models as in the work by Wu (2005) for the USA, Carboni (2011) for Italy and Haegeland and Moen (2007) for Norway. They find that the estimated additionality of tax credit is higher than that of public grants. Their estimates also suggest that the hypothesis of perfect crowding out between private and public funds can be rejected. For the Spanish economy, Marra (2008) finds that tax credits are more effective than public grants in stimulating private R&D investment and they display greater effectiveness in SMEs. In turn, Busom et al. (2011, 2012) analyze the probability of using these instruments jointly and results support the hypothesis that tax incentives and public grants are not substitutes from a company perspective. Summing up, these results, although valuable, are not enough to understand the differences in R&D intensity.

The present study fits within this last group of papers and provides a flexible and useful framework that identifies the potential determinants of R&D investment making possible an assessment of the effects of tax credits and public grants (see "Appendix 1"). For this purpose, we use a sample of manufacturing firms that conduct R&D in a period of expansion for the Spanish economy (1995–2005). One of the advantages of such sample is that offer the possibility to split it among firms that only receive tax credits and firms that receive the two public instruments simultaneously. The differences in results could be justified by the fact that tax credit is more frequently applied for companies that invest in R&D projects without specific quality requirements. However, public grants are for those companies whose projects are receiving a positive evaluation of the public agency that provides funds. They probably have more information about the requirements for the reception of public support (which justifies that in our sample, tax credit is applied for all firms receiving public grants).

Beside tax credits and public grants, the interest rate, the level of external debt and the productivity of R&D investment included in our model can further contribute to a better understanding of the key determinants of R&D investment. Regarding to the level of debt, empirical studies find a negative relationship between the firm′s debt ratio and R&D intensity. This may reflect that firms with higher debt pursue less R&D activities because they have no access to external funds and at the same time have to serve existing debt (Czarnitzki and Kraft 2004). In other words, high debt levels are a potential source of underinvestment. With respect to R&D productivity, Grabowski and Vernon (2000) and Mahlich and

[2] Although, academic and policy makers have made considerable effort in analyzing the input additional effects of public instruments, there is also a growing interest in the study of output additionality (e.g., increase in growth/employment/number of patents) and on behavioral additionality. This is the case when the public tools may induce changes in the firm behavior, or may change the behavior of other firms or institutions toward that firm (e.g., by receiving a type of public support, the government may certify firms and confer a *halo* or certification effect to private investors and/or banks (see Meuleman and De Maeseneire 2012).

[3] Corchuelo and Martínez-Ros (2008) show that tax incentives are little known by Spanish firms and may be used only randomly by SMEs.

Roediger-Schluga (2006) have shown the key role of such variable in the investment decisions. Nevertheless, since the reason for conducting R&D is to generate returns which in turn may influence future R&D investments, there is a theoretical endogeneity between R&D and productivity variables. However, this is unlikely to seriously affect the regression results since the link from R&D investments to R&D productivity is extremely blurred by the existence of uncertainty. In many cases, it can take years of investing before the first return is realized (Hall 2002). If the productivity of R&D comes out insignificant, this result might suggest that firms look at research opportunities with a long-term view, opening up elsewhere rather than at their own current R&D productivity when deciding their R&D investment.

Since the public support is more generous toward SMEs enterprises, it is of interest to compare the effectiveness of this policy for SMEs and large enterprises. Similarly, persistence in R&D is a key factor in the design of the tax credit and public grants because it is important to ensure that investment in R&D is undertaken by companies as a long-term strategy (regular R&D performers). To the best of our knowledge, this is the first time that both policy instruments are compared from such perspective. As we suspect, we find differences in the role played by these public policies and confirm the importance of firm size to understand them. Tax credits have a positive and significant contribution (although weak) to private R&D investments only for large firms. On the other hand, public grants are used by the SMEs firms to provide a positive signal about their projects to private investors and banks. In this way, public grants contribute to R&D investment by alleviating their financial constraints as it results in better access to external debt and in an additional source of funds.

The remainder of the paper is organized as follows. Section 2 reviews the principal features of tax credits and public grants in Spain. Section 3 shows the model used in the empirical analysis and describes the data. Results are discussed in Sect. 4. Section 5 summarizes the main conclusions.

2 Main features of tax credits and public grants in Spain

There are different financial instruments, i.e., public grants, guarantees, granted loans, as well as different fiscal instruments, i.e., allowances and tax credits through corporation tax to promote R&D investment (OECD 2005). Notwithstanding, there are significant differences in the design of these instruments, mainly on the method used to promote investment and on the quality of the projects promoted. The objective of tax credit is to reduce the after-tax price of R&D investment increasing as a result the profitability of investment projects. Tax credit presents two main disadvantages. First, it promotes any firm investing in R&D whatever the quality of the project. Second, it could punish SME or new ones because the biggest variability of their profits could leave them out of this public grant system.

R&D tax credit has been used in Spain since the entry into force of the Corporate Tax in 1978. Table 1 summarizes the principal features of tax credit from 1990 until today. As it is shown, the structure of this tool is as follows: (1) a general deduction for all firms investing in R&D (tangible and intangible assets), (2) an additional deduction for firms whose investment is larger than the average investment in the two previous years, (3) a specific deduction on researchers wages, (4) a maximum limit of deductions and finally (5) a delay on credit for firms presenting losses. The information in the table shows that the theoretical capacity of tax credit to stimulate investment in R&D progressively improved until 2006. These improvements consisted of (1) an increase in the percentage of deduction, which rose to 30 % from 2000 onward, (2) the introduction from 1993 onward of an increased percentage when the investment in a specific year exceeded the average of the two previous years, (3) the inclusion in the tax credit design of a specific deduction for the wages paid to researchers, (4) an increase in the limit to which the deduction was applicable and (5) a sharp increase in the number of years in which companies can defer the application of credit accrued due to the existence of losses.

Comparative studies show that the Spanish tax credit system has traditionally been very generous compared to other OECD countries (see Warda 2001, 2002). Nonetheless, in Spain, the number of firms applying deductions for R&D investment is very small. According to the data from the Spanish Tax Agency (AEAT from its Spanish acronym), there are a small number of firms applying for tax credits and there are big differences in the amount of credit according to a firm′s size. For example, in 2005, 3,674

Table 1 Design of tax credit since 1990

Period	Basic percentage of deduction (i)	Increased percentage (ii)	Percentage of expenditure on personnel (iii)	Limit of deduction (iv)	Deferral of deduction (years) (v)
1990–2002	15	No	–	25 (a)	5 (b)
1993–1995	15(c)/30 (d)	30 (c)/45 (d)	–	35 (c)	5
1996–1999	20	40	–	35	10
2000–2001	30	50	10	45	10
2002–2003	30	50	10	45	15
2004	30	50	20	50	15
2005	30	50	20	50	15
2006	30	50	20	50	15
2007	27	46	18	50	15
From 2008	25	42	17	50	15

Notes (a) from 1991 (b) from 1988 (c) fixed assets (d) intangibles (e) from 1995

firms applied for tax credit; which means < 1 % of companies that paid the corporate tax that year (506,094 firms).These statistics also show that tax credit for R&D applied to firms invoicing more than 5 million Euros (large firms according to Spanish fiscal law) was on average 195,448 Euros and 7,020 Euros on average for SMEs (Romero et al. 2010).

Public grants reduce the overall cost of investment projects by offering financial resources with no economic cost for companies. In contrast to tax credit, public grants are usually performed through public calls (in the European, national or regional context). This kind of instrument is very useful for those firms or activities with high initial costs or for those with a large degree of uncertainty on their results. For example, projects focused on the development of new medicines that must be approved by government. Public agencies (national o regional) use social welfare criteria—where the gap among private and social profitability is higher—to accept or refuse a project. Specifically the criteria followed are three. First, if the projects are developed by new firms, if firms perform basic research and if there is firm cooperation. Second, if the firm′s activity is strategic, and finally, if projects are located in less developed regions (Pereiras and Huergo 2006). Public grants from the different agencies represent approximately 18 % of R&D investment in Spain, while around 26 % of companies that undertake innovation receive some type of public grants.[4] The data available from the Spanish National Agency for Entrepreneurial Innovation (CDTI from its Spanish acronym) show that the average public grant per project has increased along the period analyzed: 50,230 Euros in 1997, 71,305 Euros in 2000 and 86,309 Euros in 2005 (Cotec 2012). Contrary to what happens with the tax credit, there is no official information about the average public grants related to firm size.

3 Model and data

Following the approach proposed by, among others, Whited (1992), Hubbard et al. (1995), Gilchrist and Himmelberg (1995), Bond et al. (2003) and Romero-Jordán et al. (2009), we have developed the following model (see "Appendix I" for more details):

$$R_{it} = \alpha_1\,\mathrm{AP}_{it-1} + \alpha_2\,\mathrm{MP}_{it} + \alpha_3\,\mathrm{FC}_{it} + \alpha_4\,D_{it} + \alpha_5\,\mathrm{Tax}C_{it} + \alpha_6\,\mathrm{Public}\;G_{it} + \eta_{it} + \varepsilon_{it} \qquad (1)$$

where R is the R&D investment rate, AP is the average productivity of R&D investment, MP is the marginal productivity of R&D investment, FC is the financial cost of debt, D is the level indebtedness, $TaxC$ is the amount of tax credit generated by R&D investment,

[4] This latter figure is, for example, slightly higher than the same figure in Germany and lower than the one in Finland where the proportion of R&D investment in terms of GDP is greater in both cases than in Spain.

Table 2 Standard descriptive statistics

	Mean	SD	Min.	Max
Full sample				
R&D investment	1.844	18.752	1.000	1,391
Average productivity	103.224	158.400	1.426	914.1
Interest rate	0.032	0.011	0.007	0.098
External debt	0.496	0.357	0.000	1.000
Tax credit	0.061	0.114	8.80e − 07	1.000
Public grants	0.969	9.292	0.000	350.1
Number of firms	941			
Large firms				
R&D investment	1.732	13.544	1.000	831.5
Average productivity	77.003	4,105	1.608	663.0
Interest rate	0.031	0.010	0.007	0.098
External debt	0.448	0.342	0.000	1.000
Tax credit	0.131	0.138	0.004	1.000
Public grants	0.945	10.726	0.000	350.1
Number of firms	455			
SMEs				
R&D investment	1.956	22.776	1.000	1,391
Average productivity	154.923	261.453	2.285	1,657
Interest rate	0.033	0.011	0.007	0.098
External debt	0.582	0.369	0.000	1.000
Tax credit	0.033	0.087	8.80e-07	1.000
Public grants	1.036	2.209	0.004	24.5
Number of firms	486			
> 10 years permanent R & D investment				
R&D investment	1.377	3.160	1.000	142.3
Average productivity	35.210	47.779	2.902	844.1
Interest rate	0.030	0.009	0.007	0.072
External debt	0.402	0.327	0.000	1.000
Tax credit	0.160	0.141	0.004	1.000
Public grants	0.584	1.553	0.000	26.7
Number of Firms	238			
≤10 years permanent R & D investment				
R&D investment index	2.038	22.221	1.000	1,391
Average productivity	122.196	148.285	5.901	728.5
Interest rate	0.032	0.011	0.007	0.098
External debt	0.562	0.363	0.000	1.000
Tax credit	0.043	0.097	8.80e − 07	1.000
Public grants	1.334	12.873	0.000	350.1
Number of firms	703			

Source Own elaboration

See "Appendix 2" for more details about the construction of the variable*s*

and finally, *Public G* is the amount public grants linked to R&D investment (all variables are expressed in logarithms). Also η_i is the time-invariant individual effect, and ε_{it} is the idiosyncratic error term.

To estimate our model, we use a panel of manufacturing firms during the period 1995–2005. Data has been obtained from the survey of Spanish manufacturing firms (ESEE from its Spanish acronym). Table 2 summarizes the main features of the companies analyzed according to two criteria: (1) size and (2) the degree of persistence in R&D investment. The procedure used to construct each of these variables is shown in the "Appendix 2". Regarding size, large companies are those with more than 200 employees and SMEs otherwise. This is the approach commonly used in studies referred to Spain where EESE is used. We have also considered a threshold of 10 years to capture the specific behavior of firms where R&D investment has a higher degree of persistence over time. Two groups of firms have been considered for this purpose: (1) companies that invest more than 10 years and (2) companies investing 10 years or less. On average, the number of years in which the company invests is 13 years in the first group and 3 years in the second one. In the sample, there are 941 firms: 455 are large and 486 are SMEs. Also, there are 238 companies that have invested in R&D more than 10 years and 703 firms that have invested a number of years lesser or equal to 10.[5] As usual, table shows the mean, standard deviation and minimum and maximum of the variables analyzed in our model.

The results show that the R&D investment and the average productivity are higher in SMEs although the deviation is much higher in the latter. With respect to financing costs, the average interest rate applicable to the SMEs is 3.29 % while in large firms is of 3.05 %. Similarly, the level of debt in SMEs is 58.16 and 44.78 % for large firms. In other words, on average, SMEs are more in debt and have a greater financial cost. For every Euro of R&D investment (including current and capital expenditures), large firms get a price after corporate tax (1-h) of 0.86 Euros, while the

[5] In this group, 46 firms were formed in 1995 or later. In other words, only 6.5 % of the firms that invest less or equal than 10 years are aged fewer than 10. In fact, the average age of firms investing in R & D over 10 years is 37.18. The average age of firms investing < 10 years is 30.19.

Table 3 R&D determinant factors

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large firms	III SMEs	IV >10 years permanent R&D investment	V ≤10 years permanent R&D investment
Average productivity	0.85 (3.01)**	0.36 (4.73)**	0.78 (3.01)**	0.28 (4.02)**	1.04 (2.59)**
Interest rate	−0.06 (−0.68)	−0.02 (−0.57)	0.05 (0.25)	0.06 (0.84)	−0.21 (−1.24)
External debt	−0.09 (−2.00)**	−0.01 (−1.18)	−0.32 (−2.19)**	−0.03 (−1.93)**	−0.14 (−1.60)*
Tax credits	−0.03 (−0.50)	0.16 (2.41)**	−0.03 (−0.72)	0.14 (1.89)**	−0.03 (−0.59)
Joint significance *F* test	$F(4{,}548) = 2.97$	$F(4{,}343) = 8.03$	$F(4{,}189) = 2.73$	$F(4{,}287) = 6.55$	$F(4{,}257) = 2.17$
Individual effects *F* test	$F(422{,}548) = 1.13$	$F(253{,}343) = 3.60$	$F(180{,}189) = 1.11$	$F(146{,}287) = 0.76$	$F(275{,}257) = 1.04$
Hausman test	$\chi^2(4) = 46.49$	$\chi^2(4) = 26.27$	$\chi^2(4) = 9.46$	$\chi^2(4) = 7.89$	$\chi^2(4) = 32.49$
Under-identification test (Kleibergen-Paap rk LM statistic)	$\chi^2(1) = 28.90$	$\chi^2(1) = 38.75$	$\chi^2(1) = 14.57$	$\chi^2(1) = 32.77$	$\chi^2(1) = 17.35$
Weak identification test (Kleibergen-Paap rk Wald F statistic)	43.71 [16.38/8.96]	208.75 [16.38/8.96]	48.47 [16.38/8.96]	165.98 [16.38/8.96]	26.12 [16.38/8.96]
Overidentification test (Sargan-Hansen J statistic)	0.00	0.00	0.00	0.00	0.00

Firms with tax credits. Dependent variable: $L\hat{I}_{it}$

In brackets, critical value computed by Stock and Yogo (2005) and 10/15 % maximal IV size

* Parameter significant at 90 %

** Parameter significant at 95 %

Source own elaboration

equivalent figure in SMEs is slightly higher reaching 0.96 Euros. In other words, on average, the tax saving generated by the tax credit is slightly lower in SMEs. Finally, on average, public grants account for 94.5 % of spending on R&D investment in large companies and 100.3 % in SMEs.[6] Consequently, the results show that public grants are more favorable for SMEs than for large companies. The opposite is true for the tax credit.

The results in Table 2 also show important differences when we consider the degree of persistence in R&D investment. Specifically, the companies where the degree of persistence is smaller than the threshold of 10 years have a higher level of external debt and have a higher interest rate. On average, the tax saving generated by the investment-tax credit is greater in companies with a higher degree of persistence (0.16); by contrast, the role of public grant is slightly smaller (58.4 %).

4 Results

According to our strategy, we perform separate estimations for companies that only receive tax credit (Table 3) and for companies that use tax credits and public grants jointly (Table 4). Every table includes

[6] A value > 100 % can be obtained in those cases where the entire public grant is received in a year although the duration of the investment project is greater than a year.

Table 4 R&D determinant factors

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large firms	III SMEs	IV >10 years permanent R&D investment	V ≤10 years permanent R&D investment
Average productivity	1.05 (4.60)**	0.53 (4.67)**	1.69 (4.49)**	0.33 (3.20)**	1.69 (4.26)**
Interest rate	−0.10 (−1.29)	−0.06 (−1.16)	0.06 (0.49)	0.01 (0.22)	−0.49 (−1.70)**
External debt	0.03 (1.06)	0.04 (2.20)**	0.05 (0.78)	0.03 (2.31)**	0.02 (0.22)
Tax credits	0.10 (1.70)**	0.16 (2.04)**	0.19 (0.89)	0.10 (1.45)*	0.17 (1.59)*
Public grants	−0.02 (−1.42)*	−0.01 (−0.85)	−0.07 (−1.88)**	−0.01 (−1.38)*	−0.09 (−1.73)**
Joint significance *F* test	$F(5,438) = 7.04$	$F(5,331) = 5.95$	$F(5,91) = 4.27$	$F(5,302) = 3.54$	$F(5,131) = 6.03$
Individual effects *F* test	$F(247,438) = 1.68$	$F(182,331) = 2.30$	$F(75,91) = 1.79$	$F(111,302) = 2.31$	$F(135,131) = 0.85$
Hausman test	$\chi^2(5) = 94.67$	$\chi^2(5) = 55.91$	$\chi^2(5) = 29.23$	$\chi^2(5) = 29.01$	$\chi^2(5) = 37.12$
Under-identification test	$\chi^2(1) = 39.81$	$\chi^2(1) = 37.25$	$\chi^2(1) = 8.03$	$\chi^2(1) = 30.46$	$\chi^2(1) = 15.37$
(Kleibergen-Paap rk LM statistic)					
Weak identification test	70.41 [16.38/8.96]	174.19 [16.38/8.96]	49.51 [16.38/8.96]	127.62 [16.38/8.96]	36.32 [16.38/8.96]
(Kleibergen-Paap rk Wald F statistic)					
Overidentification test	0.00	0.00	0.00	0.00	0.00
(Sargan-Hansen J statistic)					

Firms with both subsidies and tax credits. Dependent variable: $L\hat{I}_{it}$

In brackets, critical value computed by Stock and Yogo (2005) and 10/15 % maximal IV size

* Parameter significant at 90 %

** Parameter significant at 95 %

Source own elaboration

also results for subsamples: (1) large *versus* SMEs and regular R&D performers (more than 10 years) *versus* occasional R&D performers (less or equal than 10 years). The results obtained in Tables 3 and 4 show that the *F* test of individual effects rejects the null that $\eta_i = 0$ allowing unobservable heterogeneity to be captured through an individual-specific effects in the expression (1) (Baltagi 2008).[7] A Hausman-based test has been conducted and results confirm the existence of endogeneity only for average productivity.[8] In addition, a robustness check has been conducted including in Eq. (1) a time trend and time firm-level control variables. Results also confirming the existence of endogeneity in average productivity (see "Appendix 3" for more details).

[7] Three alternative estimation techniques are applied to the panel: pooled OLS, IV two-step OLS and two-step GMM first differences. These results are available from the authors upon request.

[8] We use the Hausman *F* test to contrast endogeneity in average productivity, interest rate, external debt, tax credits and public grants, with statistic values (an *p* values in brackets) of $F(1,546) = 1{,}391.81$ [0.00], $F(1,487) = 0.67$ [0.41], $F(1,500) = 1.59$ [0.21], $F(1,549) = 0.80$ [0.37] and $F(1,417) = 0.24$ [0.63], respectively. The null hypothesis is that these variables are exogenous. This hypothesis can be rejected at the 5 % level in case of average productivity, which implies that average productivity is endogenous.

To overcome endogeneity, an instrumental variable two-step GMM estimator allowing for fixed effects (IV-GMM) has been used. An advantage of IV estimator is that makes possible to obtain an unbiased estimation which is consistent with the parameters (Wooldridge 2002). In addition, a GMM estimator in which lagged levels of the endogenous variables are also used as instruments reduces these biases (Arellano and Bover 1995). Moreover, the IV-GMM estimator proposed by Schaffer (2010) and Baum et al. (2003) provides an autocorrelation-robust covariance matrix and standard errors robust to heteroskedasticity. As usual, average productivity has been instrumented with its own lag. Both Tables 3 and 4 report a full diagnostics to check the validity of the instrument (for a discussion see Baum et al. 2007): (1) the Anderson and Kleibergen-Paap (2007) rank LM test for under-identification, (2) the Stock and Yogo (2005) weak instrument test[9] and finally (3) the Sargan-Hansen-J statistics for over identifying restrictions.[10] Results confirm the validity of the average productivity lag as instrument. In other words, such a lag is not correlated with the error term and at the same time is strongly correlated with the instrumented variable.

The comparison for regression results in the two full samples (reported in column I from Tables 3 and 4)[11] is supportive of the suspect drawn up in this paper: The role that public policies play for firm R&D investment is different depending if the firm only receive tax credits or the firms receive tax credits in addition to public grants. For firms receiving only tax credits, results show that firms do not consider this instrument as a determinant in their decision to invest in R&D. To be able to claim tax credits, firms must finance projects with own or other private external resources first and later should have positive taxable income. We believe this is one of the reasons why tax credits is not a determinant factor for these firms. The results are different for those firms that use these policy instruments jointly; in this case both tools are determinant of their R&D investment. In this subsample, it appears to be a substitutive relationship between public and private R&D investment. According to the estimation results for the whole sample, one additional 1 % of funding leads to an increase in total R&D investment of 0.10 % in the case of tax credits. Therefore, part of the funds received from tax incentives replaces private financing. In case of public grants, we have obtained a full crowd-out effect with a value lower than one (close to zero) and negative (−0.02).

Firms that only receive tax credits show that external debt has a negative and significant influence on their R&D investment, which could indicate a sign of financial constraints in this group of firms, as it is shown in Corchuelo (2006) and Marra (2007). On the contrary, firms receiving both public tools do not show credit constrains. A requirement of quality is a main condition for the reception of public grants, which might explain that firms use this support to certificate the quality of their projects to private investors and banks instead of stimulating R&D investments (Meuleman and De Maeseneire 2012). If public grants mitigates financing constraints, they may be effective tools to induce R&D investment despite they do not show input additional effects (Takalo and Tanayama 2010; Feldman and Kelley 2006). Hence, in the presence of uncertainty, receiving a public grant might act as an observable indicator of the R&D project's quality that reduce uncertainty and facilitate the access to external debt (Hauessler et al. 2009). On the other hand, the main determinant for their R&D investments in both samples is the productivity of R&D, which indicates the contribution of the current projects' profitability to R&D investment. This result might suggest that firms look at research opportunities with a short-term view. Lastly, the interest rate variable, which approximates the uncertainty assumed by companies in their R&D investments (see Goel and Ram 2001), has the negative sign expected. But this variable is not significant in most of the subsamples.

We think that by discriminating according to firm size (columns II and III in Tables 3 and 4) and by the degree of temporal performance of R&D (columns IV

[9] Stock and Yogo (2005) classify a group of instruments as weak, or "performing poorly", if the bias of IV estimator relative to the bias of the OLS, or alternatively the statistic, could exceed several relative thresholds (in this study we use 10 and 15 % maximal IV size). The instrumental variable estimator relative bias is < 10/15 %.

[10] Under the null hypothesis that the instrumental variables are valid, the Hansen test is distributed as a chi square with degrees of freedom equal to the number of over identifying restrictions.

[11] From expression (13), we exclude marginal productivity taking into account the possible existence of multicollinearity. Otherwise, the results with this variable were not different from the results presented in Tables 3 and 4. These results are available from the authors upon request.

and V in Tables 3 and 4), we are going to be able to characterize better the effects of these instruments and their association with the other firms' R&D determinants. Regarding to firm size, several studies have shown the central role played by this variable in explaining the sensitivity of R&D investment to public policies (this is the case of Corchuelo 2006; Lach 2002; Kasahara et al. 2011; González et al. 2005).[12] We find that tax credits produce the same partial crowding-out effect in firms receiving only tax credits and those that use both instruments.

The investment-tax savings elasticity is 0.16. As a result, if the tax savings generated by tax credit increase by 1 % then investment increases less than proportionately (with a value of 0.16 %). Results confirm that tax credits are, therefore, an ineffective tool to boost R&D investment. The tax credit simply works as a reduction in the tax burden in corporate tax more than an economic stimulus that can help firms to change the investment decisions on whether to invest and even when to invest. Notwithstanding, evidence obtained in this paper is in line with Koga (2003) for Japanese firms, Baghana and Mohnen (2009) for Canadian firms and Marra (2008) and Corchuelo and Martínez-Ros (2010) for Spanish firms. Their results also show that tax credits have a significant effect in large firms although the size of the effect is small. In our results, for this type of firms, we do not find credit constrains and the contribution of R&D productivity to R&D investment, although positive and significant, is lower than in other groups.

Results differ further between the two groups of SMEs. The main determinant for SMEs that only receive tax credits is the productivity of R&D, while tax credits have no impact on their R&D decisions. In this group, results show that SMES are credit constrained. This is in line with empirical evidence that reports that a great fraction of SMEs would be more likely to be credit constrained for their R&D projects (Hoffman et al. 1998). In the group of firms that also receive public grants, results are different. First, we find that they have a significant, but weak crowd-out effect (with a negative value close to zero, −0.07). Although the existence of full crowd out is not a frequent result in the literature, some of the papers find that this hypothesis cannot be ruled out for some firms (this is the case of Busom 2000, for Spain and Wallsten 2000, for USA). An explanation for this result is that firms use the public support as a mechanism to alleviate financial constraints on R&D investment. This is an interesting result showing that financing restrictions not only depend on firms' characteristics but also in the type of public support that the firm receives.

The high impact of the productivity of R&D on the R&D investment for SMESs (1.69) can be viewed as an indication of the profitability of their projects. Evidence indicates that there is a relationship between firm size and the productivity of R&D, which shows that productivity results are often larger for the smaller firms (Doraszelski and Jaumandreu 2011). The role of uncertainty is stronger in R&D investment than in other types of investments. Then, productivity of R&D includes a compensation for the uncertainties inherent in the R&D process.

In the estimation of the model, we also distinguish across regular and occasional R&D performers. In this sense, following Steicher (2004), firms which regularly perform in R&D investment might conceivably exhibit a weaker reaction to funding than firms which perform R&D only intermittently. We do not find evidence to support this hypothesis. If we analyze the group of regular R&D performers, we find that public instruments are significant determinants of R&D investment (either in the group of firms that only receive tax credits and in the group of firms that additionally receive public grants). For those firms that only receive tax credits, investment-tax credit elasticity is close to the value computed for large firms (0.14), and we find that these firms are credit constrained. In the case of firms that use both tools, we find similar results for tax credits, although the value is lower (0.10) and the contribution of public grants shows a full (although weak) crowding-out effect. Also, as it is expected, these firms do not have signs of being credit constrained. In case of occasional R&D performers, the group of firms that only receive tax credits show that this instrument is not a relevant determinant in their decision. For firms that receive both instruments, we obtained the same contribution of public instrument than in the case of the regular R&D performers that receive these two instruments.

12 But our evidence differs from Berubé and Mohen (2009) in their analysis, focused on innovation output measures, conclude that firms using tax credits and public grants are more effective than firms using only tax credits, but firm size is not a relevant variable for the analysis.

Finally, we find an interesting result when we compare the contribution of R&D productivity to R&D of regular performers with the occasional R&D performers. It is clear that firms that perform R&D only occasionally assume higher levels of uncertainties in their projects than regular R&D performers. Such result shows that the uncertainties inherent in the R&D process are economically significant and matter for firms' investment decisions being higher for occasional R&D performers.

5 Concluding remarks and policy implications

Despite substantial growth, the literature on the effect of public R&D support on private R&D has suffered from the inconclusiveness of its findings. For these reasons, it is of central interest to gain a deeper understanding on the interrelations between effects of public support and the response of firms to these policy tools, especially with regard to different firms′ characteristics. This study has aimed to contribute to the literature primarily by establishing a flexible framework, which includes policy and non-policy determinants. Our results suggest that it doesn′t exist not a uniform effect (either positive or negative), but a set of differential effects of public R&D support. These effects depend on the type of public policy the firm receive (only tax credits or additionally public grants) and the firm characteristics.

Evidence obtained for the Spanish manufacturing firms does not confirm the existence of input additionality effects in tax credits and public grants. Regarding tax credit, results show firstly that the elasticity investment-tax savings generated by tax credit is 0.17 in the best case. Secondly, the evidence reflects that credit has some effect, although very weak, in large firms and companies that invest persistently in R&D. It is doubtful that the investment decisions of these companies would depend crucially on the tax credit, although it would be desirable to analyze these issues using a qualitative approach. Therefore, tax savings generated by tax credit is, in practice, an ex post premium rather than an ex ante stimulus. Consequently, the results offer important doubts about the maintenance of R&D tax credit in the Spanish corporate tax.[13]

[13] The repealing of this deduction would increase corporate tax revenues in 2013 by 1.5 % (about 280 million Euros).

Unlike tax credit, the financial viability of a R&D project can be different if the company receives a public grant. In this sense, results show that public funds are used as a substitutive source of funds for the firms, especially for SMEs and companies with lower R&D experience. In these groups of firms, we have detected financial constrain problems that are alleviated in the case they are recipients of public grants. This is an interesting result showing that financing restrictions not only depend on firm's characteristics but in the type of public support that the firm receives.

Our findings are robust to a number of different specifications and point to significant implications for the future design of public policies to promote R&D: The cut in the resources dedicated to this type of high value-added programs could have negative effects on the overall volume of investment. In a context of severe financial constraints as existing at present, we believe that elimination of the tax credit and the allocation of these resources to projects with high added-value and high risk via subsidies is an option to be considered.

6 Appendix 1: model

A firm's challenge is how to maximize the present discounted stream of net dividends, π_{it}:

$$\mathrm{Max}\,\pi_{it}(R_{it}) \tag{2}$$

where the stock of R&D in period t is R_{it}. The variable π_{it} is defined as:

$$\pi_{it} = (1-\mu_{\mathrm{t}})[p_{it}F_{it}(R_{it},\cdot) - r_{it}(r_{\mathrm{t}},\theta_{it})d_{it}I_{it}] - G_{it}(I_{it},\cdot) - (1-h_{it})I_{it} + s_{it}I_{it} \tag{3}$$

being:
μ_{t}: percentage of taxation of Corporation Tax
p_{it}: price of output
F_{it}: function of real company revenue
R_{it}: stock of R&D
I_{t}: investment in R&D
r_{it}: rate of interest of external financing used in investment in R&D;
r_{t}: interest rate free of risk
θ_{it}: risk premium of external financing
d_{it}: proportion of investment in R&D financed by external funds

G_{it}: adjustment costs function
h_{it}: tax credit for investment in R&D
s_{it}: proportion of investment in R&D financed by subsidies.

The financial restriction of the non-negativity of dividends is

$$\pi_{it} > 0 \tag{4}$$

For the sake of simplicity, it is assumed that perfect competition exists in the capital markets (see for example Hubbard et al. 1995). The accounting equation which identifies the R&D stock generated by the company over time corresponds to

$$R_{it} = I_{it} + (1-\delta)R_{it-1} \tag{5}$$

where the stock of R&D in period t is R_{it}. I_{it} is the investment in R&D in that same period, and $\delta$is the rate of economic depreciation. Assuming that investment in R&D takes at least 1 year to produce revenue, the first-order condition regarding the investment level is

$$\begin{aligned}\frac{\partial\pi_{it}}{\partial I_{it-1}} = (1-\mu_t)\left[p_{it}\frac{\partial F_{it}(\cdot)}{\partial R_{it}}\frac{\partial R_{it}}{\partial I_{it}}\frac{\partial I_{it}}{\partial I_{it-1}} - r_{it}d_{it}\frac{\partial I_{it}}{\partial I_{it-1}}\right] \\ - \frac{\partial G_{it}(\cdot)}{\partial I_{it-1}} - (1-h_{it})\frac{\partial I_{it}}{\partial I_{it-1}} + s_{it}\frac{\partial I_{it}}{\partial I_{it-1}}\end{aligned} \tag{6}$$

Expression (6) displays the impact of investment in R&D performed in the period $t-1$ upon the flow of dividends. $G(.)$ is the linear function of adjustment costs defined as

$$G_{it}(I_{it}, R_{it}, Y_{it}) = I_{it}\left(\frac{F_{it-1}}{R_{it-1}}\right)\lambda_{it} \tag{7}$$

$G(.)$ captures the potential loss of output occurring during the maturity period of an investment project in R&D, as a result of managerial and organisational practices, x-inefficiency, learning-by-doing, etc. (see Comin 2004). $G(.)$ is positively related to three factors:

(1) The level of net investment. The functional form for adjustment costs implies that marginal adjustment costs are zero when net investment is zero.
(2) The cost per monetary unit spent on R&D investment. As an indicator of this cost, use is made of the average productivity of the R&D stock observed in the period $t-1$ (F_{it-1}/R_{it-1}). Consequently, the adjustment cost's function decreases with the size of the capital stock, as the evidence available reflects (see Meghir et al. 1996).
(3) The number of periods elapsing from the beginning of the project until the results are fully incorporated into the production process (for a discussion, see Romero-Jordán et al. 2009). Unfortunately, λ is not directly observable.

$$\begin{aligned}\frac{\partial G_{it}}{\partial I_{it-1}} &= \lambda_t\left[-(1-\delta_t)\frac{F_{it-1}}{R_{it-1}} - I_{it}\frac{F_{it-1}}{R^2_{it-1}}\right] \\ &= -\lambda_t F_{it-1}\left[\frac{1-\delta_t}{R_{it-1}} + \frac{I_{it}}{R^2_{it-1}}\right]\end{aligned} \tag{8}$$

Inserting the Eqs. (8) in (6) given that $\left(\frac{\partial I_t}{\partial I_{t-1}}\right) = -(1-\delta_t)$ and that $\left(\frac{\partial R_{it}}{\partial I_{it}}\right) = 1$. Thus, the expression (6) is transformed in

$$\begin{aligned}&(1-\mu_t)(1-\delta)\left[-p_{it}\frac{\partial F_{it}}{\partial R_{it}} + r_{it}d_{it}\right] \\ &\quad + \lambda_{it}F_{it-1}\left[\frac{(1-\delta)}{R_{it-1}} + \frac{I_{it}}{R^2_{it-1}}\right] + (1-h_{it})(1-\delta) \\ &\quad - s_{it}(1-\delta) \\ &\quad = 0\end{aligned} \tag{9}$$

Multiplying the two sides of equation (9) by R_{it-1} and clear the term I_{it}/R_{it-1} on the left side of the equation,

$$\begin{aligned}\lambda_t F_{it-1}\frac{I_{it}}{R_{it-1}} = (1-u_t)(1-\delta_t)R_{it-1}\left[p_{it}\frac{\partial F_{it}}{\partial R_{it}} - r_{it}d_{it}\right] \\ - (1-\delta_t)\lambda_t F_{it-1} \\ - (1-\delta_t)(1-h_{it})R_{it-1} \\ + (1-\delta_t)s_{it}R_{it-1}\end{aligned} \tag{10}$$

Dividing the previous expression by $(1 - \delta)\lambda_{it}F_{it-1}$ resulting

$$\begin{aligned}\frac{I}{(1-\delta_t)R_{it-1}} = \frac{(1-u_t)}{\lambda_t}\frac{R_{it-1}}{F_{it-1}}\left[p_{it}\frac{\partial F_{it}}{\partial R_{it}} - r_{it}d_{it}\right] - 1 \\ - \frac{(1-h_{it})}{\lambda_t}\frac{R_{it-1}}{F_{it-1}} + \frac{1}{\lambda_t}s_{it}\frac{R_{it-1}}{F_{it-1}}\end{aligned} \tag{11}$$

To simplify the above expression, we define the reciprocal of the average productivity of the R&D stock as $\Omega^R_{it-1} = \frac{1}{\frac{R_{it-1}}{F_{it-1}}}$. Note that in addition to the average productivity, the Eq. (10) incorporates as determinant of R&D investment the marginal productivity, with the variable $\frac{\partial F_{it}}{\partial R_{it}}$. Taking common factor on the right side of the equation [10] yielding:

$$1 + \frac{I_{it}}{R_{it-1}(1-\delta)} = \Omega^R_{it-1}\frac{1}{\lambda_{it}} \times \left\{(1-\mu_t)\left[P_{it}\frac{\partial F_{it}}{\partial R_{it}} - r_{it}d_{it}\right] - (1-h_{it}) + s_{it}\right\} \quad (12)$$

The right side of (12) can be identified as a R&D investment rate (see among others Hubbard 1998; Gilchrist and Himmelberg 1999 and Marra 2007). It can be assumed that the marginal product of the R&D stock between two consecutive periods is approximately constant, so that $\partial F_{it}/\partial R_{it} \equiv \partial F_{it-1}/\partial R_{it-1}$. Taking logarithms for both sides of the previous expression, the following results:

$$L\hat{I}_{it} = L\Omega^R_{it-1} - L\lambda_{it} + L\left[(1-u)p_{it}\frac{\partial F_{it}}{\partial R_{it}}\right] + L[(1-u)r_{it}] + Ld_{it} + L(h_{it}) + Ls_{it} + L\Phi_{it} \quad (13)$$

where $\hat{I}$ is the R&D investment rate of the firm and Φ_{it} are the crossed effects, defined as:

$$\Phi_{it} = \left\{ \begin{array}{l} \frac{1}{[(1-u)r_{it}d_{it}]\left(\frac{1}{h_{it}}-1\right)s_{it}} - \frac{1}{(1-u)p_{it}\frac{\partial F_{it}}{\partial R_{it}}\left(\frac{1}{h_{it}}-1\right)s_{it}} - \\ - \frac{1}{(1-u)p_{it}\frac{\partial F_{it}}{\partial R_{it}}[(1-u)r_{it}d_{it}]s_{it}} + \frac{1}{(1-u)p_{it}\frac{\partial F_{it}}{\partial R_{it}}[(1-u)r_{it}d_{it}]\left(\frac{1}{h_{it}}-1\right)} \end{array} \right\} \quad (14)$$

Thus, in our model, R&D investment decision depends on the following variables: the average and marginal productivity of R&D, the financial cost of debt, the level debt, the tax credit and the public grants received. For estimation purposes, we have considered that adjustment costs, λ, are close to unity.[14] In addition, it is assumed that cross-effects are included in the individual fixed effects.

[14] This is a reasonable assumption taken into account the estimations by Meghir et al. (1996), where highly innovative firms face essentially zero adjustment costs.

7 Appendix 2: construction of the variables of the model

- *R&D stock*: Technological capital stock, R_{it}, is defined as the accumulation (net of depreciation) of annual expenditure on R&D. The stock of technological capital has been constructed for each company by means of the permanent inventory method referred to in Eqs. (15) and (16). As in the majority of existing studies for the case of Spain (see Marra 2004), a constant rate of economic depreciation of 15 % is used. In order to calculate the stock of technological capital for the first year of the sample, we have used the procedure proposed by Beneito (2001):

$$R_1 = I_1(1+m)\left[\left(1-\eta^T\right)/(1-\eta)\right] \quad (15)$$

$$\eta = (1-m)(1-\delta) \quad (16)$$

where R_1 is investment in year 1, m is the average growth rate of companies which undertake R&D, T is the number of years since the founding of the company and δ is the (constant) rate of depreciation of R&D stock. The values obtained have been deflated by industrial prices index taking 1990 as the base year.

- *Investment in R&D:* constructed on the basis of total expenditure on R&D, provided by the survey. Values have been deflated by the industrial prices index.
- *Production*: measures the production declared by the firm, deflated by the industrial prices index.
- *Productivity of R&D stock*: production divided by the stock of R&D.
- *Rate of interest of debt*: constructed as a weighted average of the financing costs of the firm:

  Current cost of short-term debt with credit entities

Table 5 R&D determinant factors

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large firms	III SMEs	IV >10 years permanent R&D investment	V ≤10 years permanent R&D investment
Average productivity	0.97 (2.79)**	0.42 (4.57)**	0.82 (2.87)**	0.34 (4.06)**	1.25 (2.14)**
Interest rate	0.12 (0.79)	0.04 (1.07)	0.14 (0.43)	0.18 (1.30)*	−0.06 (−0.27)
External debt	−0.09 (−1.98)**	−0.02 (−1.16)	−0.32 (−2.15)**	−0.03 (−2.03)**	−0.15 (−1.47)*
Tax credits	−0.01 (−0.12)	0.19 (2.40)**	−0.03 (−0.54)	0.17 (2.34)**	−0.003 (−0.05)
Time trend	0.06 (1.70)**	0.02 (2.22)**	0.03 (0.64)	0.03 (1.64)*	0.09 (1.14)
Joint significance *F* test	$F(5,547) = 2.52$	$F(5,342) = 5.90$	$F(5,188) = 2.16$	$F(5,286) = 4.73$	$F(5,256) = 1.88$
Individual effects *F* test	$F(422,547) = 1.01$	$F(253,342) = 3.29$	$F(180,188) = 1.06$	$F(146,286) = 0.70$	$F(275,256) = 0.87$
Hausman test	$\chi^2(5) = 44.88$	$\chi^2(5) = 28.50$	$\chi^2(5) = 9.53$	$\chi^2(5) = 8.53$	$\chi^2(5) = 28.23$
Under-identification test	$\chi^2(1) = 23.17$	$\chi^2(1) = 41.45$	$\chi^2(1) = 13.47$	$\chi^2(1) = 31.75$	$\chi^2(1) = 11.39$
(Kleibergen-Paap rk LM statistic)					
Weak identification test	33.59 [16.38/8.96]	162.83 [16.38/8.96]	40.90 [16.38/8.96]	116.06 [16.38/8.96]	15.59 [16.38/8.96]
(Kleibergen-Paap rk Wald F statistic)					
Overidentification test	0.00	0.00	0.00	0.00	0.00
(Sargan-Hansen J statistic)					

Firms with tax credits. Dependent variable: $L\hat{I}_{it}$(Including time trend)

In brackets, critical value computed by Stock and Yogo (2005) and 10/15 % maximal IV size

* Parameter significant at 90 %

** Parameter significant at 95 %

Source own elaboration

Average cost of long-term debt with credit entities
Average cost of long-term debt with other external funds

- *Public grants*: defined as the sum of all the public grants (both Spanish and European) for investment in R&D obtained annually by the firm divided by annual expenditure on R&D.
- *External debt financing investment in R&D:* corresponds to the percentage of long-term debt in total expenditure on R&D.
- *Tax credit*: captures the deductions for R&D applied by the firm in Corporation Tax per Euro of R&D investment. The survey only offers data for the years 2001–2005. The values for previous years have been calculated according to the procedure described in Romero-Jordán and Sanz-Sanz (2007).
- *Prices:* the price index employed has been constructed on the basis of the variation in sales prices provided by the survey.

8 Appendix 3: robustness check

The cumulative nature of R&D could be a problem when endogeneity needs to be overcome. To complete

Table 6 R&D determinant factors. Firms with tax credits

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large firms	III SMEs	IV >10 years permanent R&D investment	V ≤10 years permanent R&D investment
Average productivity	0.98 (2.79)**	0.41 (4.42)**	0.83 (2.77)**	0.34 (3.97)**	1.31 (2.13)**
Interest rate	0.05 (0.34)	0.05 (1.03)	0.16 (0.50)	0.12 (1.09)	−0.17 (−0.64)
External debt	−0.09 (−1.85)**	−0.01 (−1.01)	−0.31 (−1.86)**	−0.03 (−1.84)**	−0.14 (−1.27)
Tax credits	−0.01 (−0.12)	0.21 (2.36)**	−0.03 (−0.74)	0.22 (2.93)**	−0.002 (−0.02)
Joint significance *F* test	$F(13{,}539) = 1.31$	$F(13{,}334) = 2.48$	$F(13{,}180) = 1.26$	$F(13{,}278) = 2.01$	$F(13{,}248) = 1.05$
Individual effects *F* test	$F(422{,}539) = 1.00$	$F(253{,}334) = 3.23$	$F(180{,}180) = 1.02$	$F(146{,}278) = 0.68$	$F(275{,}248) = 0.83$
Hausman test	$\chi^2(13) = 52.16$	$\chi^2(13) = 59.71$	$\chi^2(13) = 15.39$	$\chi^2(13) = 11.10$	$\chi^2(13) = 33.33$
Under-identification test	$\chi^2(1) = 23.15$	$\chi^2(1) = 40.94$	$\chi^2(1) = 13.35$	$\chi^2(1) = 32.10$	$\chi^2(1) = 10.64$
(Kleibergen-Paap rk LM statistic)					
Weak identification test	33.01 [16.38/8.96]	156.52 [16.38/8.96]	37.25 [16.38/8.96]	113.44 [16.38/8.96]	14.84 [16.38/8.96]
(Kleibergen-Paap rk Wald F statistic)					
Overidentification test	0.00	0.00	0.00	0.00	0.00
(Sargan-Hansen J statistic)					

Dependent variable: $L\hat{I}_{it}$ (including time dummies)

In brackets, critical value computed by Stock and Yogo (2005) and 10/15 % maximal IV size

* Parameter significant at 90 %

** Parameter significant at 95 %

Source own elaboration

the endogeneity analysis discussed in Sect. 4, a robustness check is made by including separately in our model: (1) a time trend and (2) an additional time firm-level control variable. In both cases, a Hausman-based endogeneity test has been conducted. In the model with a time trend, the null of exogeneity can only be rejected at the 5 % level in the case of average productivity which implies that this variable is endogenous.[15] The same result has been found in the model including a time firm-level control variable.[16] Therefore, the results for endogeneity do not change with respect to basic specification. So, in that case, this contrast indicates the existence of endogeneity only in average productivity, which is the instrumented regressor in an instrumental variable two-step GMM estimator with fixed effects (IV-GMM).

The results for both alternatives estimations are shown in Tables 5, 6, 7 and 8 As it is shown, results are

[15] The results for the endogeneity test for average productivity, interest rate, external debt, tax credits and public grants are, respectively, the following: (p values in brackets) $F(1{,}545) = 1{,}369.92$ [0.00], $F(1{,}486) = 0.07$ [0.79], $F(1{,}499) = 1.64$ [0.20], $F(1{,}548) = 0.54$ [0.46], $F(1{,}416) = 0.58$ [0.45].

[16] The results for the endogeneity test for average productivity, interest rate, external debt, tax credits and public grants are, respectively, the following: (p values in brackets) $F(1{,}537) = 1{,}350.10$ [0.00], $F(1{,}478) = 0.02$ [0.88], $F(1{,}491) = 1.24$ [0.27], $F(1{,}540) = 0.28$ [0.59], $F(1{,}408) = 0.72$ [0.39].

Table 7 R&D determinant factors

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large sirms	III SMEs	IV >10 years permanent R&D investment	V ≤10 years permanent R&D Iinvestment
Average productivity	1.11 (4.35)**	0.55 (4.41)**	1.87 (4.31)**	0.33 (3.08)**	2.82 (3.00)**
Interest rate	0.001 (0.01)	−0.01 (−0.11)	0.22 (1.26)	0.02 (0.55)	−0.09 (−0.28)
External debt	0.03 (0.88)	0.04 (2.07)**	0.05 (0.67)	0.03 (2.24)**	0.07 (0.51)
Tax credits	0.13 (1.92)**	0.17 (2.12)**	0.28 (1.19)	0.11 (1.51)*	0.43 (1.78)**
Public grants	−0.02 (−1.49)*	−0.01 (−0.85)	−0.08 (−1.90)**	−0.01 (−1.37)*	−0.18 (−2.05)**
Time Trend	0.02 (1.83)**	0.01 (1.23)	0.06 (1.59)*	0.002 (0.51)	0.30 (2.11)**
Joint significance *F* test	$F(6{,}437) = 5.85$	$F(6{,}330) = 5.02$	$F(6{,}90) = 3.51$	$F(6{,}301) = 2.97$	$F(6{,}130) = 2.84$
Individual effects *F* test	$F(247{,}437) = 1.58$	$F(182{,}330) = 2.22$	$F(75{,}90) = 1.58$	$F(111{,}301) = 2.25$	$F(135{,}130) = 0.44$
Hausman test	$\chi^2(6) = 93.15$	$\chi^2(6) = 60.73$	$\chi^2(6) = 26.13$	$\chi^2(6) = 27.42$	$\chi^2(6) = 19.71$
Under-identification test	$\chi^2(1) = 35.45$	$\chi^2(1) = 31.29$	$\chi^2(1) = 8.43$	$\chi^2(1) = 26.38$	$\chi^2(1) = 9.03$
(Kleibergen-Paap rk LM statistic)					
Weak identification test	60.29 [16.38/8.96]	143.39 [16.38/ 8.96]	44.18 [16.38/ 8.96]	115.29 [16.38/ 8.96]	13.30 [16.38/8.96]
(Kleibergen-Paap rk Wald F statistic)					
Overidentification test	0.00	0.00	0.00	0.00	0.00
(Sargan-Hansen J statistic)					

Firms with both subsidies and tax credits. Dependent variable: $L\hat{I}_{it}$(including time trend)

In brackets, critical value computed by Stock and Yogo (2005) and 10/15 % maximal IV size

* Parameter significant at 90 %

** Parameter significant at 95 %

Source own elaboration

Table 8 R&D determinant factors

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large firms	III SMEs	IV >10 years permanent R&D investment	V <= 10 years permanent R&D investment
Average productivity	1.13 (4.21)**	0.54 (4.24)**	2.21 (4.20)**	0.34 (3.10)**	2.88 (2.69)**
Interest rate	−0.05 (−0.57)	−0.05 (−0.84)	0.28 (1.27)	−0.01 (−0.26)	−0.12 (−0.35)
External debt	0.03 (0.93)	0.04 (2.04)**	0.12 (1.30)*	0.03 (2.15)**	0.10 (0.68)
Tax credits	0.13 (1.81)**	0.15 (1.83)**	0.55 (1.44)*	0.11 (1.40)*	0.43 (1.55)*

Table 8 continued

Variables	IV two-step GMM (fixed effects)				
	I Full sample	II Large firms	III SMEs	IV >10 years permanent R&D investment	V <= 10 years permanent R&D investment
Public grants	−0.02 (−1.55)*	−0.01 (−1.14)	−0.09 (−1.69)**	−0.01 (−1.55)*	−0.18 (−2.12)**
Joint significance F test	$F(14{,}429) = 2.73$	$F(14{,}322) = 2.49$	$F(14{,}82) = 1.81$	$F(14{,}293) = 1.47$	$F(14{,}122) = 1.42$
Individual effects F test	$F(247{,}429) = 1.50$	$F(182{,}322) = 2.11$	$F(75{,}82) = 1.18$	$F(111{,}293) = 2.20$	$F(135{,}122) = 0.38$
Hausman test	$\chi^2(14) = 92.44$	$\chi^2(14) = 61.42$	$\chi^2(14) = 26.84$	$\chi^2(14) = 30.14$	$\chi^2(14) = 17.65$
Under-identification test	$\chi^2(1) = 33.50$	$\chi^2(1) = 27.83$	$\chi^2(1) = 11.01$	$\chi^2(1) = 27.97$	$\chi^2(1) = 8.01$
(Kleibergen-Paap rk LM statistic)					
Weak identification test	55.91 [16.38/8.96]	123.97 [16.38/8.96]	34.31 [16.38/8.96]	113.84 [16.38/8.96]	10.65 [16.38/8.96]
(Kleibergen-Paap rk Wald F statistic)					
Overidentification test	0.00	0.00	0.00	0.00	0.00
(Sargan-Hansen J statistic)					

Firms with both subsidies and tax credits. Dependent variable: $L\hat{I}_{it}$(including time dummies)

In brackets, critical value computed by Stock and Yogo (2005) and 10/15 % maximal IV size

* Parameter significant at 90 %

** Parameter significant at 95 %

Source: own elaboration

very similar to those in basic specification. Average productivity is the main determinant of R&D investment in all cases analyzed, and the role of tax credit and public grants is similar to that in the basic estimations showed in Sect. 4.

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