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THE IMPACT OF R&D SUBSIDIES ON R&D EMPLOYMENT COMPOSITION *

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ABSTRACT: In this paper we examine the impact of subsidies granted at national and regional levels on a set of R&D employment variables and, specifically, we seek to identify the existence of the behavioural additionality effects of these public subsidies on firms' R&D human resources. We begin by assessing the effects of public funds on R&D private expenditures and on the number of R&D employees, and then focus on their impact on the composition of human resources engaged in R&D as classified by occupation and level of education.

The data used correspond to the Spanish Technological Innovation Panel for the period 2006-2011. To control for selection bias and endogeneity, a combination of non-parametric matching techniques are implemented. After ruling out the existence of crowding out effects, our results show that R&D subsidies increase the number of R&D employees. However, no increase is found in the average level of qualification of R&D staff members in subsidized firms. All in all, the effects of public support are heterogeneous being dependent on the source of the subsidy and the firms' characteristics.

JEL Codes: O38, J24, H25, C14

Keywords: R&D subsidies, R&D employment, matching estimators, technology policy

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1. Introduction

Governments implement a broad mix of innovation policy tools in order to correct market failures. Such public intervention is justified from a social point of view as a means of preventing underinvestment in R&D activities. However, the ultimate goal of this policy is concerned not simply with increasing private R&D expenditure, but rather with boosting productivity, economic growth, employment and welfare.

R&D subsidies, together with tax incentives, have been broadly used as technology policy tools to correct market failures. Their implementation implies the use of public funds and, consequently, their impact has been assessed from various perspectives. Until recently, such evaluations have focused primarily on two criteria: the ability of subsidies to induce more R&D expenditure (input additionality) and their ability to generate more innovative outputs (output additionality).

These criteria are today frequently complemented with that of so-called behavioural additionality, whereby the impact of public interventions is assessed in terms of the behavioural changes that are experienced by firms. Empirical evidence for this approach is relatively scarce because of the difficulties faced in making behavioural additionality operational (Gok and Edler, 2012). However, various studies (Falk, 2007; Autio et al., 2008; Clarysse et al., 2009) have explicitly analysed behavioural changes in public supported firms, providing empirical evidence of the effects of behavioural additionality in public R&D funded projects.

It seems, therefore, that public interventions can have behavioural effects and instigate change in the human resources of subsidized firms, playing a key role in strengthening human capital and technological know-how and in enhancing technology management, through the recruitment of personnel with specific capabilities and knowledge to undertake R&D projects.

Here, after assessing the effect of R&D subsidies granted in Spain on the number of R&D employees, our main objective is to analyse the impact of subsidies on firm behaviour in terms of the recruitment of highly qualified human resources. To detect such effects we analyse the way in which R&D subsidies can affect the composition of human resources engaged in R&D. First, we analyse occupation type and the responsibilities of R&D personnel, distinguishing between researchers, technicians and auxiliary staff. Second, we consider the level of education distinguishing between PhD holders, graduates and engineers, short-cycle tertiary and personnel with other non-tertiary education. Such an analysis affords us a better understanding of the impact of these subsidies on the quantity and quality of R&D employees, and allows us to identify how subsidized firms allocate their additional funds to R&D projects as far as their human resources are concerned.

R&D subsidies are granted by public agencies operating at different levels of government that may have different policy objectives (Afcha, 2011; Blanes and Busom, 2004). Consequently, it is important to distinguish between levels of government (Zúñiga-Vicente et al., 2014), since these public agencies may influence firms' demands for a specific type of R&D personnel to carry out their R&D projects depending on the selection criteria of the agencies. We focus our analysis on national and regional R&D subsidies, which are the most important in Spain in terms of the number of recipient firms and the size of budget. However, in the estimations, we control for other sources of public support including European R&D subsidies.

The database used in this paper corresponds to the Spanish Technological Innovation Panel (PITEC) for the period 2006-2011. This database, built with the Spanish version of the Community Innovation Survey (CIS), provides information on the occupation and educational level of R&D workers. The availability of these data means we are able to overcome the limitations identified by Thomson and Jensen (2013) regarding the lack of information that studies in this field face when seeking to examine the skills of individual R&D workers. Our estimation of the impact of subsidies is carried out by combining two non-parametric matching techniques – the coarsened exact matching (CEM) and the propensity score matching (PSM) methods.

The rest of the paper is organised as follows. Section 2 presents the analytical framework and summarises the empirical evidence concerning R&D subsidies and their impact on R&D employment. Section 3 describes the dataset and the methodology used in the evaluation approach. In section 4 we discuss the main results of the estimations and section 5 concludes.

2. Literature review and analytical framework

2.1. Public subsidies and R&D employment

In recent years the literature devoted to evaluating the impact of technology policy interventions has grown rapidly. This literature analyses the impact of policy tools on firms' innovative performance indicators. The empirical evidence (David et al., 2000; García-Quevedo, 2004; Cerulli, 2010; Zúñiga-Vicente et al., 2014) has focused primarily on evaluating the impact of public funding on R&D inputs, measured through R&D expenditures and R&D effort, and on R&D outputs such as patents, sales of new products or number of new products and processes.

Recent papers propose complementing measures of input and output additionality with analyses of changes in firms' behaviour attributable to public interventions. Falk (2007) finds that scope additionalities, in the form of more cooperation or more challenging R&D projects, arise when multiple policy interventions or continuous public support is provided. Autio et al. (2008) show that collaborative R&D programs, by enhancing the identification of subsidized firms with a community of practice, enhance learning outcomes in these firms. Similarly, Clarysse et al. (2009) shed some light on the organizational factors affecting input additionality. Specifically, their results point to the fact that companies reporting the highest learning outcomes also continue to invest in their absorptive capacity, and so they provide evidence of a strong correlation between input additionality and behavioural additionality.

Numerous studies evaluating public intervention in technology policy analyse the impact of subsidies on private R&D expenditures and, although some examine the effects of subsidies on employment as a complementary indicator (Eshima, 2003; Lerner, 1999; Link and Scott, 2013; Wallsten, 2000), the number of studies using R&D employment explicitly as the dependent variable is very limited.

Some studies (Goolsbee, 1998; Wolf and Reinthaler, 2008) use aggregate data to analyse the effect of subsidies on wages and on the number of employees. While

Goolsbee's (1998) conclusions support a crowding out effect, showing that public financing increases the remuneration of the R&D personnel already engaged in R&D activities, Wolff and Reinthaler's (2008) findings show that R&D subsidies stimulate both variables positively but that the effect is greater on R&D wage levels.

Other papers use microdata to examine directly the effects of public subsidies on R&D employment. Falk (2006) evaluates the impact of public subsidies in Austria using the number of R&D workers as the dependent variable. Her results indicate a small but significant effect of R&D subsidies on R&D employment. Specifically, a 1% increase in public funds generates a 0.04% rise in R&D personnel. Piekkola (2007) reports positive effects for Finland in its proportion of R&D employees as well as productivity growth improvements in subsidized firms. These results coincide with those obtained by Ali-Yrkkö (2005), also for Finland, when analysing the impact of R&D subsidies and distinguishing between domestic and non-domestic employees and R&D and non-R&D employees. His results show that subsidies have a positive impact only in the case of domestic employees engaged in R&D activities.

These studies capture the impact of subsidies on the increase in the number of R&D employees. Yet, the effect induced by subsidies on the composition of human resources engaged in these R&D activities has not, to date, been analysed in detail.

Human resources constitute a key component in innovation and economic growth processes, as well as being a priority objective for technology policy. For instance, Griffith et al. (2004) stress the importance of human capital for technical change and innovation in OECD countries.

Lundvall (2008) reports that higher levels of education allow adequate competences for assimilating technological change to be acquired. This, therefore, increases the importance of university graduates, since individuals with higher levels of education serve as a vehicle for the construction of innovative skills and learning capabilities, two essential elements for taking advantage of technological opportunities. In addition, the complexity and tacit nature of scientific knowledge implies a high cost in terms of knowledge transfer and exploitation. The recruitment of PhDs may help to overcome these problems, providing better ties with universities and public research institutions

(García-Quevedo et al., 2012) and serving as channel to bring the knowledge embodied in these graduates into industry (Stephan et al., 2004).

Empirical approaches have identified a positive link between human resources and R&D and innovation from a variety of perspectives. Leiponen (2005) shows that there are significant complementarities between technical skills and innovation and that human capital is positively associated with innovative performance. As such, innovation policies need to take into account these interactions. Piva and Vivarelli (2009) conclude that there is a positive link between ex-ante available skills and R&D investment and that the improvement in a firm's manpower skills may be beneficial for its innovation strategies. D'Este et al. (2014) also report a positive relationship between human capital and innovation showing that having a strong skill base has a significant impact on attenuating deterrents to innovation.

The concept of behavioural additionality emphasizes the role of human resources as a key component in any evaluation of the benefits derived from public policies. This perspective, grounded in resource-based theory, stresses the importance that unique, rare and hard to imitate resources represent for firms and, hence, the importance of taking policy impact into account in terms of quality improvements recorded among employees. Georghiou and Clarysse (2006) argue that, rather than a simple increase in the number of employees, public funds should serve as an incentive to increase the level of qualifications of R&D staff members, enabling firms to attract the skills that allow them to acquire competitive advantages.

Accordingly, public intervention should be oriented towards promoting the recruitment of human capital with the skills needed to acquire and use specific knowledge (Georghiou and Clarysse, 2006). Recent contributions (Huergo and Trenado, 2010; Takalo et al., 2013) show that the degree of technical challenge and the potential of R&D projects positively influence the likelihood of receiving public subsidies. The development and execution of high-technology projects may require incrementing the human capital and making changes to the educational composition of the R&D staff.

Georghiou and Clarysse (2006) describe various mechanisms of public intervention that may change firms' strategies. The effects of technology policy may result in the acquisition of higher levels of knowledge, the upgrading of personnel skills and improvements in technology management, as well as changes in the scale and length of R&D projects. Clarysse et al. (2009) is one of the few studies to provide empirical evidence of the impact of subsidies on organizational learning and technology management. However, to the best of our knowledge, no previous study has examined the impact of subsidies on the composition of R&D staff.

2.2. Effect of R&D subsidies provided by different levels of government

Recent evaluations stress the importance of considering the different levels of government that intervene in technology policy, because they may well use R&D subsidies to target different policy goals (Afcha, 2011; Blanes and Busom, 2004; Czarnitzki and Lopes-Bento, 2011; Fernández-Ribas, 2009; García-Quevedo and Afcha, 2009).

At the country level, a distinction should be drawn between subsidies originating from central government and those from regional governments. The rationale underpinning technology policy at the national level is the existence of market failures (OECD, 2008) and, thus, it seeks the creation of incentives to enhance the level of investment in R&D. Various empirical studies associate the objectives of national governments with the so-called "picking-the-winners" strategy, which tends to focus its efforts on strengthening technological levels in medium-large firms, belonging to high or medium-high technology sectors and with projects requiring large amounts of private investment. Blanes and Busom (2004) show that national and regional R&D subsidies in Spain seek to fulfil different objectives and that firm size and human capital intensity play an important role in the concession of grants at the national level where subsidies are oriented, in the main, towards promoting high level, commercially viable, technological projects.

The participation of regional governments in innovation and technology policy has increased substantially over the last two decades. Initially, these interventions were also made with the aim of correcting market failures. More recently, however, regional interventions have been more closely concerned with solving systemic failures. This perspective identifies other sources of failure that might hinder the smooth operation of innovation systems and constitute obstacles for the development and economic growth of a region. Indeed, institutions such as the OECD (2008) suggest that technology policy at the regional level could be more effective in solving problems associated with i) a lack of innovative capacity in regional firms, ii) rigidities that prevent the correct configuration of institutions; iii) network and coordination problems related to the interaction between agents in the innovation system; iv) a failure to adapt frameworks so as to regulate economic activities and; v) lock-in failures motivated by practices and behaviour inhibiting the adoption of new methods.

The objectives of regional technology policy may thus differ from those planned by national governments, and, as in most regions in Spain, they tend to be more closely oriented to developing technological clusters, broadening the base of small and medium-sized firms performing R&D activities and, more generally, to reducing technological gaps between innovative and non-innovative firms.

These differences in the technology policy goals of the two levels of government suggest that there may well also be differences in the impact of their respective subsidies on business R&D expenditures and employment. National and regional agencies do not have the same criteria for selecting the R&D projects that are to receive subsidies and, as a result, different impacts can be expected. These differences may be especially marked in the case of R&D employment, whose main characteristics tend to be specifically related to the type of project proposed by the firms that apply for grants from public agencies.

3. Data and methodology

3.1 Data description

The data used in this study are taken from the Spanish Technological Innovation Panel (PITEC). This database is compiled by the National Statistics Institute (INE) in Spain, which is advised in this task by a group of university researchers and sponsored by the Spanish Foundation for Science and Technology (FECYT) and the COTEC Foundation. The panel database includes the annual Survey of Innovation in Companies, carried out annually by the INE, following the guidelines of the OECD's Oslo Manual, which means it can be compared with similar European innovation surveys (Community Innovation Survey). The panel comprises 12,283 firms drawn from industrial sectors and services for the period 2003-2011. Here, we limit our study to the period 2006-2011, given that some questions in the survey have changed over the years and some information is not available for the early years. The PITEC provides detailed information about R&D employment by occupation and level of education, or formal qualification, of the R&D personnel. Its panel structure allows lagged variables to be included to control for previous performance and the granting of subsidies so that the potential persistency in the allocation of public funds can be taken into account.

Occupation data are classified in line with the criteria proposed by the OECD (2002) in the Frascatti Manual, distinguishing between researchers, technicians and other support staff employed in R&D activities measured in full-time equivalent (FTE). Education data also adhere to OECD guidelines and include the following categories: PhD holders (ISCED level 6), Graduates or Engineers (ISCED level 5a), Short-cycle tertiary (ISCED level 5b) and personnel with non-tertiary education (ISCED level 4 or below). Although a new version of the International Standard Classification of Education was published in 2011, we use the categories from the 1997 version as these are the ones employed in the PITEC between 2006-2011.

Table 1 shows the distribution of R&D personnel classified by occupation and level of education. By occupation, researchers constitute the main group followed by technicians and auxiliary staff in R&D. By level of education, graduates and engineers are the most numerous group followed by personnel with short-cycle tertiary education, those with non-tertiary education and, finally, PhD holders. The number of PhD holders in firms in Spain falls below the respective OECD and EU averages (Cruz-Castro and Sanz-Menéndez, 2005) but it presents an upward tendency in recent years.

Table 1

3.2 Methodology

The evaluation of technology policy has evolved rapidly in recent years and traditional problems in the evaluation of R&D subsidies such as sample selection and endogeneity have been broadly analysed in the empirical literature (Cerulli, 2010). The first of these problems, sample selection, arises because it is only possible to observe the performance of those firms participating and obtaining public subsidies. In the second case, the variables used to measure the effect of public intervention (e.g. private effort in R&D) could be endogenously determined, if we assume that those firms performing a greater effort in R&D are more likely to be subsidized.

Most of the recent studies implement non-parametric matching techniques to solve these problems. Propensity score matching (PSM), as a matching method for the estimation of the average treatment effect on the treated (ATT), has been used extensively in empirical studies on the effects of R&D subsidies (see, among others, Aerts and Schmidt; 2008; Almus and Czarnitzki, 2003; Carboni, 2011; Czarnitzki and Licht, 2006; Czarnitzki and Lopes Bento, 2013; Duch et al. 2009; Duguet, 2004; González and Pazó, 2008; Herrera and Nieto, 2008).

Following this literature, we use non-parametric techniques. Specifically, two matching techniques are combined in order to ensure the maximum degree of similarity between control and treated groups. These techniques are, in first place, coarsened exact matching (CEM) as proposed by Blackwell et al. (2009) and, in second place, PSM as proposed initially by Rosenbaum and Rubin (1983). Using CEM prior to the implementation of the subsequent matching techniques is suggested as an appropriate procedure for improving the quality of matching and the inferences after PSM (Blackwell et al., 2009; Iacus et al., 2012).

Matching techniques allow the comparison of two potential results, W^1 for those firms receiving the subsidy, D=1, and W^0 for those firms not receiving any treatment (D=0). Matching is based on the conditional independence assumption (CIA), which states that, conditional on a vector of covariates, potential outcomes W^1 and W^0 are independent of D. In order to ensure the fulfilment of this assumption it is necessary to observe exhaustively those variables affecting, simultaneously, the outcome and the reception of the treatment.

The rich information provided by the PITEC allows us to select an exhaustive set of variables and to include similar variables to those used in previous evaluation studies (see, among others, Aerts and Schmidt, 2008; Almus and Czarnitzki, 2003; Hussinger, 2008). The availability of panel data offers, *a priori*, the possibility to combine matching techniques with a diff-in-diff estimator. However, the lack of information regarding the length of each project and the existence of multiple treatments, whose concessions follow irregular trajectories over time, hinder the establishment of a baseline year without loss of data. Yet, the sample size, and complete coverage for the remaining years, reduces this limitation when using PSM techniques.

Taking advantage of the panel data structure, some lagged variables are included to control for the path dependence associated with the innovation process. This persistence is especially remarkable in the cases of R&D effort and the granting of subsidies (Antonelli and Crespi, 2013; González and Pazó, 2008). In addition, and as well as controlling for the granting of subsidies in t-1, we need to control for subsidies granted by other levels of government when estimating the effects of one specific source of public financing.

In order to guarantee the similarity between treated and control groups, the first method used is the CEM, which allows covariates to be matched exactly. The main advantage of CEM over other matching methods is that the maximum imbalance of the empirical distribution is bounded through an ex-ante user choice. By choosing this imbalance ex-ante, users can control the amount of imbalance in the matching solution. By so doing this method improves the estimation of causal effects and reduces differences between treated and control groups (Collins et al., 2011; Finseraas et al., 2011; Mason et al., 2011).

Iacus et al. (2012) outline how to apply the CEM technique. This can be summarised in the following four steps:

1. Begin with the covariates X and make a copy – denote here as X*.

2. Coarsen X* according to user-defined cutpoints or CEM's automatic binning algorithm.
3. Create one stratum per unique observation of X*, and place each observation in a stratum.
4. Assign these strata to the original data, X, and drop any observation whose stratum does not contain at least one treated and one control unit.

CEM generates intervals for each variable submitted for comparison, coarsening observations into different subgroups. After coarsening each variable into substantively meaningful groups, the exact matching algorithm is applied to the coarsened data, and the values of the matched data are retained uncoarsened.

The measure of imbalance in CEM is obtained following this formula:

$$\mathcal{L}_1(\mathrm{f},\mathrm{g}) = \frac{1}{2}\sum_{\ell_1 \dots \ell_k} \left| \mathrm{f}_{\ell_1 \dots \ell_k} - \mathrm{g}_{\ell_1 \dots \ell_k} \right| \tag{1}$$

where $\mathrm{f}_{\ell_1 \dots \ell_k}$ and $\mathrm{g}_{\ell_1 \dots \ell_k}$ are relative frequencies of the discretized variables $X_{1 \dots} X_{k,}$ for the treated and control units respectively.

CEM estimation includes, in addition to the variables described in Table A.1, the number of researchers, technicians and auxiliary staff engaged in R&D for the period t-1 and a set of industrial and service sector dummies.

The data for the period 2006-2011 are treated as pooled data; thus, observations for the same firm in different years are considered as independent observations. However, to avoid comparing observations that correspond to the same firm in different years, matching is restricted to firms in the same year.

After discarding variables with missing values, CEM is run, providing a sample of treated and control firms, matched exactly for a set of variables. The next step involves the implementation of a second matching method, in this case propensity score matching (PSM), on the sample previously matched with CEM. Rosenbaum and Rubin

(1983) define the PSM as the conditional probability of being treated given a vector of covariates X:

$$p(X) \equiv P(D=1|X) = E(D|X) \tag{2}$$

where D is a dummy variable indicating the exposure to the treatment that takes values D= (0,1). Then, ATT is formulated as follows:

$$\tau = p(x)\Big|D=1\left\{E\left[Y(1)|D=1, P(X)\right] - E\left[Y(0)|D=0, P(X)\right]\right\} \tag{3}$$

where:

Y(1) represents the expected outcome of subsidized firms.

Y(0) represents the outcome of non-subsidized firms.

The nearest neighbour matching (NNM) algorithm is used to construct the treatment and control groups. The two nearest neighbours for each subsidized firm, restricted to common support, are obtained. The set of variables used in the matching are described in Table A.1.

4. Results

4.1 Validity of the matching

The validity of the matching constitutes a crucial step when applying these techniques and the main objective is to determine the similarity in the joint distribution of the set of covariates corresponding to the control and treated groups (Stuart, 2010). A common procedure to confirm if both groups are properly balanced involves estimating the standardized bias or the difference in standardized means, before and after matching (LaLonde, 1986; Rosenbaum and Rubin, 1983).

$$\frac{\bar{x}^1 - \bar{x}^0}{\sqrt{(Var(x^1) - Var(x^0))}} . 100 \tag{4}$$

Table A.2 in the appendix shows, for each variable, the reduction in bias achieved in the difference between treated and controls after the second matching procedure (PSM). The mean values for these variables do not present significant differences between controls and treated groups receiving national, regional or total public funding for R&D.

4.2 The impact of R&D subsidies

Table 2 shows the results corresponding to the effect of public subsidies for R&D activities, without distinguishing between the levels of government. These results correspond to different categories of R&D expenditures and number of R&D employees classified by type of occupation and level of education.

In line with previous studies for Spain (Busom, 2000; González and Pazó, 2008; González et al., 2005; Herrera and Heijs, 2007), these results reveal the existence of financial additionality in private R&D expenditures. The estimations also show that public subsidies have a positive and significant effect on the number of R&D employees. These findings suggest, firstly, that there is a sufficient number of qualified employees to cover the firms' demand for R&D workers. Secondly, public subsidies afford firms the possibility of increasing their stock of human capital and of allocating it to develop R&D projects, a fact that, according to the empirical literature, has positive effects on a firm's productivity and innovative performance.

Our data allow us to examine not only the magnitude of the increase in the number of R&D employees, but also to analyse the behaviour of subsidized firms taking into account certain characteristics of their R&D staff, such as occupation and educational level. This level of observation enables us to examine changes in the internal structure of the firm and to analyse if the subsidy induces changes in these two dimensions of R&D human resources.

By occupation, the increase in the overall size of R&D staff induced by the subsidy leads to an increase in each of the three categories (i.e., researchers, technicians and auxiliary personnel), although the greatest growth is recorded in the number of researchers. By level of education, the increase in R&D personnel corresponds mainly to a rise in the numbers of graduates followed by personnel with other non-tertiary and short cycle tertiary studies and, finally, PhD holders. In relative terms, the comparison of the structure of R&D staff (by both occupation and qualification) in the treated and control firms reveals no statistically significant differences. Thus, for example, the respective percentages of participation of researchers among R&D staff are 46.5 and 48.8% for treated and control firms. Similarly, while 6% of the R&D staff hold PhDs in the treated firms, this percentage stands at 5.7% in the controls.

These results show that subsidies generate an increase in R&D expenditures and an increase in R&D staff numbers, but that they do not bring about changes in the composition of R&D personnel. As such they are not responsible for generating any behavioural additionality effects in this specific dimension of the human capital of firms. R&D subsidies facilitate the recruitment of personnel and increase R&D staff sizes but they do not affect the decisions of the firms with regard to the composition (in terms of occupation or level of education) of their R&D staffs.

The impact of public financing may differ depending on the firms' characteristics as shown by recent empirical literature and its growing interest for analysing possible heterogeneous effects. This heterogeneity suggests that a firm's reaction to public intervention may be conditioned by specific characteristics that influence the innovation process. In line with this, several papers analyse the impact of R&D subsidies on firms according to their size (Falk, 2007; González and Pazó, 2008; Lach, 2002; Östelik and Taymaz, 2008). In this paper, the possible existence of differences attributable to firm size is also analysed. Additionally, we take into account the type of R&D performed, be it continuous or occasional in nature.

R&D subsidies are mainly granted to solve market failures and financial market imperfections that hamper access to finance for R&D projects. These failures primarily affect those firms that face difficulties in meeting the financial costs of R&D projects. Thus, differences in the impact of public subsidies on small and medium-sized firms, on the one hand, and on large firms, on the other, are expected, since the latter *a priori* face fewer financial restrictions and are less dependent on public funding. In order to test this hypothesis, ATT is estimated by splitting the sample in two groups, firms with 250 employees or less and firms with more than 250 employees (Table 2).

The results show, firstly, the financial additionality effects of R&D subsidies for both types of firm for all categories of R&D expenditures, except in the case of private R&D expenditures in large firms. Secondly, R&D subsidies have a significant impact on the number of R&D employees. Thirdly, there is an increase in most of the categories of R&D employees, by occupation and or level of education, in both types of firm with the exception of technicians and graduates in large firms. Therefore, even in small and medium-sized firms, the granting of R&D subsidies leads to the recruitment of graduates and PhD holders.

Table 2

With the aim of analysing the impact of public financing on firms performing R&D on a regular basis compared with those firms performing occasional R&D, ATT is estimated considering the frequency of R&D activities. While firms that perform R&D on a regular basis have, in general, long-term R&D strategies and stable R&D staffs, occasional performers do not, in many cases, have a formal R&D organisation. As such, different effects of public financing are expected in relation to the differences in the qualifications held by the staff members of both firm types and also depending on the characteristics of the projects subsidized.

The results show an additional effect of public subsidies on R&D expenditures and an increase in the number of R&D personnel in the two types of firm. The growth in the overall size of R&D staff attributable to a subsidy leads to an increase in each of the three categories of occupation in both cases. Nevertheless, by level of education, there is no statistically significant impact on the recruitment of PhD holders for firms performing R&D on a regular basis. By contrast, our results show that for firms performing occasional R&D, public subsidies have a positive effect on the level of education of their R&D staff with a rise in the number of PhDs recruited and significant differences in the participation of PhD holders in the structure of the R&D staffs of treated and control firms. This result suggests that occasional R&D performers face human capital shortcomings when seeking to carry out new R&D projects and that the subsidies granted to these firms have behavioural additionality effects increasing the average level of education.

4.3 The impact of subsidies according to different levels of government.

Previous analyses indicate, as discussed above, that technology policies implemented at different levels of government respond to different motivations. Table 3 shows the impact according to national and regional levels of public financing. Calls for applications for public subsidies from a specific level of government do not exclude firms already being subsidized by other levels of government. Consequently, in one given year, a firm can receive public subsidies from more than one source. To take this into account, ATT is calculated for each level of government, controlling for the possibility that subsidies may have been obtained from other public agencies. In addition, as a robustness check, Table 3 also shows the ATT estimation for those firms receiving just one subsidy in a given year, i.e. only national and only regional.

The results show that public financing (both national and regional subsidies) has a positive effect on the number of employees; however, the magnitude of this effect is greater in the case of national subsidies. The respective impacts on the level of education of R&D staff in subsidized firms also differ significantly. Thus, while national subsidies have a positive effect on the recruitment of employees holding PhDs, the effect of regional subsidies is not significant.

These results are consistent with the characteristics of the firms subsidised by the two levels of government and with the different objectives targeted by national and regional agencies respectively. Thus, Spain's national government seems to adopt a "picking-the-winners" strategy, promoting R&D and high-technology projects that require qualified personnel. By contrast, regional governments show a greater concern for promoting innovation (but not exclusively R&D) and for improving the links between the agents in their regional systems. Nevertheless, the recruitment of PhD holders attributable to national subsidies and the relative R&D staff structures of treated and control firms do not present any significant differences. These results therefore seem to confirm those obtained for total subsidies indicating that R&D subsidies do not generate behavioural additional effects in terms of the average level of qualification of R&D staff.

Table 3

5. Conclusions

This paper has analysed the impact of public subsidies on the composition of R&D employment. Despite its being a priority objective in technology policy, few studies explicitly examine this relationship. After confirming that subsidies serve to increase both total and private R&D expenditures, our estimations show that public support has a positive effect on the number of R&D employees. However, our results do not identify the existence of behavioural additionality effects. The increase in the size of the R&D staffs of subsidized firms does not lead to an improvement in the average level of qualification of the staff members. Therefore, public subsidies for business R&D projects do not seem to affect the decision of the firms with regard to the level of human capital of their R&D employees.

Our results show that when evaluating the impact of R&D subsidies it is necessary to consider the multilevel structure of governments involved in the granting of subsidies. Indeed, our findings point to significant differences depending on the level of government. At the two levels considered - national and regional - subsidies have a positive effect on the number of R&D employees but in the case of regional subsidies there is no significant effect on the recruitment of PhDs.

The analysis carried out is not free of limitations. First, as in most studies of this kind, information about the specific characteristics of the projects actually being funded is not available. Second, it is not possible to distinguish between subsidies granted by the various regional agencies that may have quite distinct innovation policy objectives. Third, the time period for which information is available is too short to distinguish between short- and potential long-term effects.

Despite these limitations, this analysis has provided information about the effects of technology policy. Firstly, it confirms the existence of financial additionality as regards R&D expenditures and employees. Secondly, the results do not show that R&D subsidies lead to significant changes in the composition of R&D staff in subsidized firms and they rule out the existence of behavioural additionality effects on the level of education of R&D personnel. Therefore, without targeting public subsidies to this specific dimension, public support does not seem to have a significant impact on the improvement of the level of education of R&D staffs. These results also support the convenience of having, as many countries do, specific programs designed to incorporate researchers and PhD holders in firms as long as the innovation policy attempts to improve the human capital level of R&D staffs.

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Table 1. R&D personnel by occupation and level of education (data in full-time equivalent, FTE)

	Occupation				Education				
Year	Researchers	Technicians	Auxiliary Staff	Total	PhD	Graduates/Engineers	Short cycle tertiary	Other non Univ.	Total
2006	2.677	0.942	2.188	5.80	0.331	1.330	2.738	1.408	5.80
2007	2.500	0.815	2.064	5.38	0.351	1.148	2.562	1.318	5.38
2008	2.596	0.793	2.121	5.51	0.391	1.173	2.639	1.306	5.51
2009	2.754	0.786	2.204	5.74	0.396	1.206	2.817	1.325	5.74
2010	2.803	0.760	2.371	5.93	0.430	1.138	3.053	1.312	5.93
2011	2.757	0.761	2.278	5.79	0.447	1.176	2.887	1.286	5.79
Total	2.677	0.808	2.200	5.68	0.391	1.192	2.776	1.325	5.68

Table 2. Impact of R&D subsidies. Subsidies from any public administration.

	Total		**250 employees or less**		**More than 250 employees**		**Continuous R&D performers**		**Occasional R&D performers**	
Variable	**Difference**	**T-stat**	**Difference**	**T-stat**	**Difference**	**T-stat**	**Difference**	**T-stat**	**Difference**	**T-stat**
Total R&D expenditures	110178.199	13.090***	68332.063	11.700***	167878.127	2.160**	86338.690	6.430***	76089.642	7.470***
Private R&D expenditures	70402.441	7.830***	46674.491	7.670***	108386.239	1.270	49622.082	3.660***	72039.418	7.240***
Internal R&D expenditures	78415.601	12.500***	48425.174	10.820***	130523.974	2.350**	65799.922	6.350***	48230.870	9.660***
Total personnel in R&D	1.215	18.020***	0.766	12.920***	2.174	2.700***	1.078	6.770***	0.630	12.020***
Research personnel	0.528	14.060***	0.317	10.130***	1.245	5.170***	0.397	5.280***	0.276	10.630***
Technicians	0.473	12.830***	0.282	9.790***	0.628	1.010	0.513	4.800***	0.234	8.530***
Auxiliary staff	0.215	12.390***	0.167	8.430***	0.301	2.470***	0.168	4.520***	0.120	7.760***
PhDs	0.072	7.540***	0.037	3.500***	0.073	2.070**	0.035	1.390	0.019	3.470***
Graduates	0.600	16.540***	0.357	11.060***	1.019	1.600	0.580	6.110***	0.310	9.590***
Short cycle tertiary	0.240	8.990***	0.135	7.170***	0.506	3.100***	0.178	3.210***	0.124	7.960***
Non university degree	0.290	10.680***	0.238	8.950***	0.576	2.450***	0.285	4.350***	0.177	8.130***

Note: Statistically significant ***99% and **95%.
R&D expenditures are expressed in Euros and personnel in FTE.

Table 3. Impact of R&D subsidies by level of government

	National R&D subsidies		Regional R&D subsidies		Only National R&D subsidies		Only Regional R&D subsidies	
Variable	**Difference**	**T-stat**	**Difference**	**T-stat**	**Difference**	**T-stat**	**Difference**	**T-stat**
Total R&D expenditures	163846.95	3.68***	78811.94	2.57***	147274.21	2.91***	31154.80	2.38***
Private R&D expenditures	120619.91	2.43***	55150.81	1.66*	100483.10	1.83*	9404.78	0.96
Internal R&D expenditures	132996.24	3.94***	48028.88	2.74***	130369.42	3.24***	20293.85	2.03**
Total personnel in R&D	1.56	4.57***	0.55	2.84***	1.58	4.16***	0.34	4.36***
Research personnel	0.79	8.02***	0.31	2.98***	0.67	7.40***	0.14	3.06***
Technicians	0.54	1.83*	0.16	1.93*	0.66	1.99**	0.13	3.78***
Auxiliary staff	0.22	5.23***	0.08	1.88*	0.25	5.53***	0.07	3.31***
PhDs	0.10	4.77***	-0.01	-0.13	0.06	2.46***	0.01	0.40
Graduates	0.88	3.34***	0.31	3.09***	0.91	3.15***	0.14	3.12***
Short cycle tertiary	0.20	4.10***	0.15	3.95***	0.20	3.62***	0.09	4.02***
Non university degree	0.37	5.28***	0.09	1.83*	0.41	5.03***	0.10	3.43***

Note: Statistically significant ***99%, **95% and *90%.
R&D expenditures are expressed in Euros and personnel in FTE.

Table A.1. Data description

Variable	Description	Obs.	Mean	Std. Dev.
National subsidies	Dummy=1 if the firm receives national subsidies, 0 otherwise	60799	0.18	0.39
Regional subsidies	Dummy=1 if the firm receives regional subsidies, 0 otherwise	60799	0.19	0.39
European subsidies	Dummy=1 if the firm receives European subsidies, 0 otherwise	60799	0.04	0.19
Total subsidies	Dummy=1 if the firm obtains receives subsidies from some administration, 0 otherwise	60799	0.29	0.45
Total subsidies in t-1	Dummy=1 if the firm receives subsidies from some administration in the previous year, 0 otherwise	60799	0.31	0.46
Internal R&D in t-1	Dummy=1 if the firm performs internal R&D activities in the previous year, 0 otherwise	60799	0.49	0.50
Patents	Dummy=1 if the firm applies for patents, 0 otherwise	60799	0.10	0.30
Training	Dummy=1 if the firm imparts training courses to its workers, 0 otherwise	60799	0.11	0.31
International and private	Dummy=1 for firms with 50% or more of foreign capital, 0 otherwise	60799	0.13	0.34
Lack of internal funds	Categorical variable between 1 (not experienced) to 4 (high importance) regarding the firm's assessment of the lack of internal funds as a factor hampering innovation activities.	60799	2.31	1.14
Group	Dummy=1 if the firm belongs to a group, 0 otherwise	60799	0.40	0.49
Size	Total number of employees	60799	312.57	1459.42
R&D cooperation	Dummy=1 if the firm engages in R&D cooperation, 0 otherwise	60799	0.19	0.39
High technology	Dummy=1 if the firm belongs to high technology manufacturing sector, 0 otherwise	60799	0.05	0.21
Medium-high technology	Dummy=1 if the firm belongs to medium-high technology manufacturing sector, 0 otherwise	60799	0.17	0.38
Medium-low technology	Dummy=1 if the firm belongs to medium-low technology manufacturing sector, 0 otherwise	60799	0.15	0.36
High technology services	Dummy=1 if the firm belongs to high technology service sector, 0 otherwise	60799	0.10	0.31
Researchers in t-1	Number of Researchers in FTE	60799	2.63	15.30
Technicians in t-1	Number of R&D Technicians in FTE	60799	2.20	12.38
Auxiliary staff in t-1	Number of R&D Auxiliary staff in FTE	60799	0.80	4.41

Table A.2. Subsidies from National and Regional administrations. Difference of means test. Control and treated groups after matching

	TOTAL SUBSIDIES				NATIONAL SUBSIDIES				REGIONAL SUBSIDIES			
	Mean			T.test	Mean			T test	Mean			T-test
Variable	Treated	Control	% bias	t	Treated	Control	% bias	t	Treated	Control	% bias	t
Total Subsidies in t-1	0.676	0.679	-0.6	-0.31	0.556	0.560	-1	-0.23	0.595	0.604	-1.1	-0.30
National Subsidies									0.131	0.126	2	0.51
Regional Subsidies					0.239	0.239	0	0.00				
European Subsidies					0.010	0.008	2.3	0.48	0.007	0.0076	-0.4	-0.09
Internal R&D in t-1	0.719	0.726	-1.6	-0.97	0.551	0.550	0.2	0.04	0.545	0.545	-0.1	-0.02
Patents	0.057	0.059	-0.9	-0.46	0.033	0.028	3.6	0.75	0.024	0.023	1	0.25
Training	0.069	0.070	-0.1	-0.06	0.057	0.051	3.3	0.71	0.040	0.039	0.8	0.20
International and private	0.029	0.033	-2.1	-1.30	0.048	0.054	-3	-0.76	0.021	0.020	0.5	0.16
Lack of internal funds	1.837	1.82	0.9	0.65	1.897	1.879	1.6	0.47	1.787	1.769	1.7	0.62
Group	0.228	0.234	-1.4	-0.84	0.267	0.253	3.1	0.85	0.176	0.165	2.9	0.97
Size	84.489	87.197	-0.4	-0.20	185.12	230.5	-3.8	-0.67	74.51	670.77	1.6	0.97
R&D cooperation	0.283	0.268	4	1.93	0.204	0.188	5.2	1.09	0.181	0.176	1.5	0.38
High technology	0.028	0.027	0.2	0.13	0.016	0.018	-1.7	-0.35	0.015	0.015	0.7	0.19
Medium-high technology	0.178	0.183	-1.3	-0.75	0.185	0.199	-4.2	-0.98	0.159	0.159	0.2	0.06
Medium-low technology	0.153	0.149	1.1	0.67	0.145	0.139	2	0.51	0.153	0.151	0.6	0.17
High technology services	0.117	0.119	-0.9	-0.47	0.105	0.114	-3.4	-0.75	0.094	0.092	0.8	0.21

Pseudo R2	LR chi2	p>chi2	Pseudo R2	LR chi2	p>chi2	Pseudo R2	LR chi2	p>chi2
0.001	10.58	0.719	0.002	6.86	0.976	0.000	2.53	1.000

2011

2011/1, Oppedisano, V; Turati, G.: "What are the causes of educational inequalities and of their evolution over time in Europe? Evidence from PISA"
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