Firm Size and Innovation Policy

Abstract

This study analyses the additionality effects of R&D subsidies on the firms' innovation activity, specifically on the way firms allocate their in-house R&D expenditures and on the economic returns of the innovation process. The magnitude of these effects have been established by taking into consideration the size of the firm, since it is a widely used variable in designing innovation policies. Our study has revealed that public funding, regardless of size, mainly stimulated investments aimed at gaining knowledge within the firm's technological domain (applied research and technological development), while it did not expand the technological knowledge frontier (basic research). The findings also show that R&D subsidies have different additionality effects on the economic returns derived from the innovation process. Although, small subsidised firms increased their private R&D effort quite significantly, they only managed to achieve an increase in the sale of products new for the firm. Meanwhile, large subsidised firms, which only increased their investments in technological development, managed to increase the sale of products new for the market.

Keywords

R&D Subsidies, Innovation Policy, Firm Size, R&D activities.

1. Introduction

During the last decades the interest in analysing innovation activity as a source of competitive advantage has increased and several authors have studied how certain firm characteristics encourage or impinge on the innovation process. In this context, some studies have focused on analysing the effect of firm size as a determining characteristic. Following the seminal work by Schumpeter (1942), there has been a wide-ranging debate on the differences and complimentary qualities of small and large firms in the face of innovation activity and technological change. According to this author, large firms have advantages in comparison with small ones when taking part in innovation activities. This hypothesis has been reviewed in various empirical studies without any definite conclusion being reached. Large and small firms do not differ just in their R&D investments but also in the management and productivity of their innovation activity (see Cohen and Keppler, 1996; Gray and Mabey, 2005; Ahuja et al. 2008).

Though no consensus has been reached in the literature, results from research have led to a change in the role assigned to large and small firms in the processes of technological change and economic development. If traditionally large firms have been the main actors, nowadays small firms are also viewed as agents of change, giving rise to employment and technological diversity which stimulates the growth and the evolution of the industry (De Jong and Vermeulen, 2006; Spencer et al., 2008). As a result, new innovation policies have sprung up with a specific recognition of firm size as a key aspect in maintaining technological diversity and industrial dynamic. Nevertheless, the design of these new polices has been made with a lack of awareness of the relationship between the variables: firm size and innovation policy.

Following the traditional approach of innovation policies evaluation (see David et al., 2000), a small group of studies have analysed how certain measures of public funding (generally R&D subsidies) impinge on some variables which represent firms' innovation activity (generally private R&D expenditures). Though these studies confirm the hypothesis that public funding has different effects on the private R&D expenditures of large and small firms, it is not clear to what extent firms gain advantage from public incentives. Estimating the effect of subsidies on the net amount of R&D expenditures does not sufficiently capture the effect of public funding on the innovation process itself. Despite the economic justification for innovation policies stressing that they guarantee the production of technological knowledge and decrease market failures which reduce incentives to innovation (Arrow, 1962), the literature provides little information with regard to the effect of public funding on creating technology knowledge or economic returns stemming from such knowledge (Cohendet and Meyer-Krahmer, 2001).

In this context, this study analyses the additionality effects that R&D subsidies have on the firms' innovation activity in the case of large, medium- sized and small firms. Estimating additionality effects entails answering the following research question: ¿Is there any difference in the firms' innovation activity when receiving subsidies compared to not receiving them?. The main contribution of this study is to determine this difference in some aspects of the firms' innovation activity which have not been previously analysed by the literature. Firstly, we analyse how R&D subsidies impinge upon the way firms allocate their R&D expenditures on basic research, applied research and technological development activities, as a proxy measure for inputs of the innovation process. Several authors have shown that R&D activities provide knowledge with a different strategic value and that firms' choice with regard to these activities changes according to firm size (Henard and McFadyen, 2005, 2006). R&D subsidies might promote investments geared to extending the frontier of firms' technological knowledge (basic and applied research) and/or going more deeply into the technological knowledge that firms already have (technological development). Secondly, we also analyse whether R&D subsidies have any influence on sales of innovative products as a proxy measure for economic returns and outputs of the innovation process. Though recent studies have found that R&D subsidies have some effect on intermediate results of this process such as patents (Czarnitzki and Licht 2006) or on the firm performance (Archibald and Finifter, 2003; Lerner, 1999; Wallsten, 2000), present literature is a long way away from establishing whether subsidised firms achieve higher economic returns from their innovation activity than non-subsidised ones. In fact, there are factors such as innovative capacity, business strategy or the market which directly impinge on these economic returns. Nonetheless, R&D subsidies are economic resources requested by firms in the framework of their R&D strategy and their effects upon economic indicators are not to be underestimated. In the analysis we use the dichotomy between "sale of products new for the firm" and "sale of products new for the market" in order to take into account the degree of novelty of innovations. The degree of novelty is one of the forces driving economic growth and could re-form the base of competition in an industry or create new ones (Audretsch and Aldridge, 2007; Tellis and Golder, 1996).

This study has the following structure: the second section presents the theoretical arguments and the hypotheses tested in the study. In the third section, details are given of the methodology used and in the fourth section the data and variables are described. The findings of the empirical analysis are discussed in the fifth section and, finally, in the sixth section, the conclusions are presented.

2. Firm size and innovation policy.

In general terms innovation polices are defined as a group of activities geared to increasing the quantity and intensity of innovation activities, which include creating, adapting and adopting new or improved products, processes and services (Lundvall and Borrás, 2005). In the literature empirical studies have used the additionality concept in order to identify the effects of these policies. This concept is defined by Buisseret et al. (1995) as something which would not have been achieved without public support. Some authors argue that the concept is originally based upon the neoclassical justification of market failure, according to which, firms have no incentives to invest in this activity at the optimum levels and public agencies should intervene to solve the problem (Metcalfe and Georghiou, 1998). Consequently, the additionality effect is expected to measure the difference between the assumed underinvestment of firms in innovation and real publicly-led investment (Luukkonen, 1998). Estimating this effect will involve comparing the situation of subsidised firms with that where there is a dearth of such policies in order to establish whether this effect is really an “additional” one (Klette et al., 2000). Recent studies have shown that there are additionality effects if the innovative activity being analysed is greater than that obtained by firms not receiving public support but who were more inclined to obtain it (Almus and Czarnitzki, 2003; Czarnitzki and Fier 2004; Herrera and Nieto, 2008). This idea can be applied to all the possible impacts of a given aid program, in such a manner that additionality effects have been found in the inputs and outputs of the innovation process (quantitative studies) and also in the behaviour and cognitive capacity of firms (qualitative studies) (see Buisseret et al., 1995; Clarysse et al., 2009).

Taking into account firm size, empirical evidence has focused on analysing input additionality effects in the context of R&D investments and has found that public funding might complement or substitute private R&D expenditures (see Table 1). Carmichael (1981) found, for example, that public funding had a greater effect on R&D expenditures in large firms than in small ones. This finding is similar to that obtained by Klette and Moen (1998), who found a complementary effect between public funding and private funding in business units of large firms. The study by Lach (2002) analysed the effect of subsidies with no significant short-term results. However, he found that, a year after obtaining the public funding, small firms showed a significant increase in their R&D expenditures. On the other hand, in a study of the Spanish case, González et al. (2005) found a complementary effect which was greater in small firms than in large ones. Unlike previous studies, these authors identified a minimum level of subsidies needed to take on R&D activities. Their study concluded that this level was smaller in large firms and greater in small ones (10 per cent and 40 per cent of their R&D expenditures, respectively). Finally, González and Pazó (2008) established that the effect of subsidies on private R&D intensity in a sample of innovative firms was higher in firms with fewer than 200 employees. This effect was also significant and positive in a second sample including innovative and non-innovative firms. One of the most important conclusions obtained from the comparative study of these two samples was that for small firms, public funding has an important role in the decision to take part in R&D activities.

(Table 1 here)

As can be seen in Table 1, these studies are not directly comparable and their results are not conclusive. The studies not only differ in their findings, the support programs analysed, the period of time evaluated and the methodology, but also in the criteria used by the authors to subdivide the sample of firms by size. Contemporary knowledge of the relationship between firm size and innovation policy is not useful for the policymaker to be able to make decisions on other aspects such as policies design, resource distribution, stimulation of certain technologies or accumulation knowledge, among others. The traditional approach of evaluating the effect on the net amount of R&D expenditures does not adequately record the impact of public funding on strategic aspects such as the process of generating technological knowledge nor does it enable us to determine whether subsidised firms gain economic returns from the innovation process.

In the case of technological knowledge generation (input additionality), Lichtenberg (1984) argued that the final impact of innovation policy on technological progress and productive growth will depend upon how public funding impacts on the way firms distribute their R&D investments. Despite the importance of this topic, we have only detected the work by Link (1992) which shows that availability of public funding makes firms alter the makeup of their in-house R&D expenditures and thus, their knowledge acquisition strategy. Basic and applied research and technological development activities provide firms with knowledge of different strategic value (Coccia and Rolfo, 2008). Such activities are developed in the early stages of the innovation process where firms run the highest risk and make decisions on their technological knowledge frontier. The most up-to-date understanding of the innovation process suggests that these activities do not take place in a linear fashion, since the appearance of a technology may stimulate the creation of new technological knowledge and vice versa (Kline and Rosenberg, 1986). Basic research activities enable firms to produce knowledge without a particular objective. Applied research generates knowledge with a specific practical aim in mind and technological development is concerned with transforming this knowledge into products and services (Beesley, 2003). Investment in basic research, in general, is long term and helps to make the firm aware of the latest technological advances in the field where they provide the basis for applied research (Henard and McFadyen, 2006). On the other hand, applied research and technological development activities generate knowledge which is closer to the technological domain of the firm and its market (Roper et al., 2004). These activities are in general short-term ones and enable firms to distance themselves from their competitors (Henard and McFadyen, 2006).

Recent studies point out that there could be differences in the choice made by large and small firms when they invest in these three types of R&D activities (Henard and McFadyen, 2005, 2006). Large firms endeavour to have a broad knowledge base to enable them to maintain their competitive advantage. These firms invest more in in-house R&D activities (Cohendet and Meyer-Krahmer, 2001; Veugelers, 1997) and can find in basic and applied research activities a way to increase the firm's scientific knowledge base in the long-term (Rafferty, 2003). On the contrary, a characteristic of small firms is that they have a narrow knowledge base due to the limitations of resources they possess (Gopalakrishnan and Bierly, 2006). Small firms are more focused on activities providing immediate solutions to critical problems and those affecting the core areas of the business, so they may be more interested in technological development activities (Corsten, 1987; Santoro and Chakrabarti, 2002).

Analysing the effect of public funding on how firms allot their R&D expenditures would make it possible to determine whether firms take advantage of public funding to expand their technological knowledge base or to exploit existing knowledge. In order to grow and survive, firms have to make decisions regarding their technological frontier and reshaping their resource base. Productive growth is not only achieved by adapting existing technologies but also by creating new ones. In-house R&D activities are a challenge for firms and policymakers, since these activities are expensive and risky. Thus, in this study the following hypothesis is proposed:

Hypothesis 1: Subsidised and non-subsidised firms show a different distribution of their in-house R&D expenditures on basic research, applied research and technological development activities, and the magnitude of this difference changes according to firm size.

In the case of economic returns (output additionality), the literature reviewed shows that in almost every case, empirical studies have estimated the effect of subsidies on private R&D expenditures without taking into consideration the influence on the economic returns of the innovation process of large and small firms (see Table 1). The commercial success of subsidised projects has been analysed in studies evaluating aid programs for small firms, such as the SBIR program (Small Business Innovation Research Program), an initiative of the United States government to subsidise R&D activities (Archibald and Finifter, 2003; Lerner, 1999; Wallsten, 2000). Although these studies show that subsidies have an effect on sales and employment of firms participating in this program, there is no definitive conclusion as to how great the effect is. Nonetheless, the study by Archibald and Finifter (2003) clearly shows that subsidies simultaneously affected inputs and outputs of the innovation process and that in this relationship there is influence from the firm's orientation towards commercial success. The study concludes that the quest for commercial success was achieved at the expense of investments in basic research and the technical competence of the firm. In this study we estimated output additionality effects by using the sale of innovative products as a proxy measure for the economic returns and the output of the innovation process. Unlike other studies, we used the dichotomy "sale of products new for the firm" and "sale of products new for the market" to take into account the degree of novelty of innovations. Some authors find that this classification is also suitable for categorising the innovative approach of small and large firms (Mosey, 2005). In accordance with Kaufmann and Tödtling (2001), the "new for the firm" category is generally associated with incremental innovations. These, if successful, could improve the firm's competitive position in the same market. The "new for the market" category is associated with radical innovations requiring more than incremental development and having no competitor in the market. Keizer and Halman (2007) argue that when firms focus on obtaining incremental innovations, they are worried about the impact they might have on profit levels, whereas in the case of radical innovations, firms are more concerned with the value of the firm and the impact of the technology on the market. Radical innovations are obtained by firms with a strong emphasis on technology and innovation since these innovations have a longer, more unpredictable life cycle and are more dependent upon the context (Ettlie et al., 1984). Whereas incremental innovations are linear, involve few resources and can include simple collaboration relationships (Keizer and Halman, 2007), they are also low-cost and can be made operative more quickly than radical innovations (Bhaskaran, 2006).

The literature analysing firm's size and the degree of novelty of innovation is scarce and not very conclusive (Oke et al., 2007). Studies have centred on the analysis of innovation outputs in large firms more than in small ones (Henderson, 1993; Oke et al., 2007; Stringer, 2000). In the case of incremental innovations, some studies conclude that large firms might obtain advantages from this type of innovation, since these innovations are constructed on existing capacities and knowledge, which is greater in these firms (Henderson, 1993). However, other authors point out that there is a greater advantage for small firms. Thanks to their flexibility and speed in introducing innovations, small firms would gain advantages from incremental innovations in highly competitive markets (Bhaskaran, 2006). In the case of radical innovations, some authors argue that the financial success of these innovations is larger in large firms than in small ones (Paulson et al., 2007), whereas others argue that they are more easily obtained in small firms because the firm itself could be based on a radical idea (Kanter, 1985; Simon et al., 2002; Stringer, 2000).

In general, the literature has not dealt with analysing how innovation policy impinges on the economic returns and the degree of novelty of subsidised products and, consequently, its contribution to economic growth is unknown. Estimating additionality effects could provide important information to policymakers for developing support measures that enable firms to gear their activity and anticipate the direction and time of entry for their innovations (Dahlin and Behrens, 2005). As a result, in this study the following hypothesis is formulated:

Hypothesis 2: Subsidised and non-subsidised firms show a different level of economic returns and the magnitude of this difference changes according to firm size.

3. Methodology

In this study a matching estimator was used to analyse the additionality effects of R&D subsidies (S_i) on firms' innovation activity (Y_i). The method specifically compares the inputs and outputs of the innovation process of firms receiving subsidies $Y_{i,s=1}$ (1) or factual state, with the results they would have obtained if they had not received them $Y_{i,\, s=1}$ (0) or counterfactual state. Because a firm *i* cannot be observed simultaneously when receiving and not receiving subsidies, the counterfactual state becomes a fundamental problem for evaluation. The matching estimator estimates the counterfactual state with information stemming from a control group made up of firms that did not receive subsidies but had a strong propensity to receive them $Y_{i,s=0}(0)$. To obtain this control group the method has to estimate, for each firm, the conditional propensity of receiving R&D subsidies (or propensity score) given a group of individual characteristics X_i. In this study we used a Probit model to estimate this propensity and analysed which conditional variables X_i influence the likelihood of obtaining subsidies (see section four).

The use of matching estimators has gained popularity in the literature that evaluates public policies because it enables the problem of distribution of aid to be borne in mind. In our case, the distribution of subsidies is not a random process because firms request subsidies and often compete for them. As a consequence, at the end of this process subsidised firms differ from those which are not. This fact produces a problem known as sample selection bias, which could skew estimates of causal effect since subsidised firms are not comparable with any other firm in the economy. The estimator reduces this bias through a process of matching between comparable units and, for this purpose uses a proximity criterion. In this way, each subsidised firm has a firm in the control group which is as similar as possible in terms of its propensity for obtaining subsidies. We have used the bias-corrected matching estimator proposed in Abadie and Imbens (2006) to make the matching process and obtain a net figure of the effect. We have also followed the recommendations in the work by González and Pazó (2008), which shows that the effect of subsidies may be overestimated if previous R&D experience (lagged outcome) and past success in application for public funding are not taken into account. As a result, in our study the selection process of similar observations was made from within the group of firms complying with the following conditions: they had a similar propensity to obtain subsidies, they belonged to the same sector of activity and were in the same situation with regard to previous R&D expenditure, and with regard to having received subsidies or not in the previous period. Once the matching process was concluded, subsequently, the bias-corrected matching indicator obtains the causal effect as the difference between the average value of a variable of interest Y_i in the group of subsidised firms $Y_{i,s=1}$ (1) and the value of this same variable in the control group $Y_{i,\, s=0}$(0). Subsidies have a positive effect if the figure for this difference is significantly higher than 0. The bias-corrected matching estimator can be represented thus:

$$\tau = \frac{1}{N_1} \sum_{i|s_i=1} [Y_{i,s=1}(1) - Y_{i,s=0}(0)]$$

Dehejia and Wahba (2002) and Abadie and Imbens (2006) carry out a thorough review of these estimators and Almus and Czarnitzki (2003) describe how they are applied to the case of innovation policy evaluation.

4. Data and variables

4.1 Data

The data used to carry out the research come from the Panel of Technological Innovation (PITEC). This panel was created with information from Spanish firms recorded by the Survey of Technological Innovation and R&D drawn up by the Instituto Nacional de Estadística in Spain. Since 2003 the panel has recorded information from more than 7 200 firms belonging to two sub-populations. The first consists of innovative firms with more than 200 employees and the second of firms which declared in-house R&D activities. The representative nature of the first subpopulation is 73% of Spanish firms and 60% in the second case. The data used in this study covers the period between the years 2003-2007. In this study a time dependence data structure was used. In the case of input additionality (hypothesis 1), we estimated the effect in the year in which the firm received the subsidies (2004) and the following year (2005). While in the case of the output additionality (hypothesis 2) we estimated the effect for 2006 and 2007. This is because in the survey the proxy for outputs measured the sales of innovative products introduced in the last three years over total sales (%). As a result, the variable in the year 2006 records the percentage of sales stemming from innovations in goods and services introduced in the period 2004-2006 and its value in 2007 records the period 2005-2007. The variable S_i , that is, whether the firm received subsidies or not in 2004, acquires its determination from lagged explanatory variables X_i, in other words, values in 2003, thereby reducing endogeneity problems and also improving the quality of matching. More information on the database and its anonymisation can be found at http://sise.fecyt.es/Estudios/PITEC.asp.

The final sample of firms used in the study was 4713 firms, who replied to the survey during the seven-year period. Of these firms, 1218 received R&D subsidies from central and regional governments. We compared the hypotheses in the total sample of firms and in three subsamples by size: large firms (more than 250 employees), medium-sized firms (50-249 employees) and small firms (1-49 employees), which contain 1971, 1543 and 1190 firms, respectively. This classification was made according to the recommendation of the European Union to facilitate comparison among countries and adjust to the reality of the Spanish production sector. Traditionally, literature has classified firms in two groups: firms with more than 200 employees and firms with fewer than 200 employees, which does not properly reflect the composition of Spanish industry. Around 70% of employment in Spain is provided by small firms with fewer than 49 employees, in comparison with an average 50% in the European Union and 36% in the United States (OECD, 2007).

4.2. Variables

The covariables vector X_i used to estimate the firms' propensity to obtain subsidies includes variables which in accordance with the literature influence this propensity (see: Acosta and Modrego, 2001; Almus and Czarnitzki, 2003; Blanes and Busom, 2004; Busom, 2000; Czarnitzki and Fier, 2002; González and Pazó, 2008). In the first place, we included variables representative of the firm's structural characteristics. Size (log of number of employees) and age (a dummy variable indicates whether the firm is newly created or not) have been considered as indicators of the firm's experience and their capacity for obtaining resources. We also included a dummy variable which indicates whether the firm is private without foreign capital, since some authors have shown that certain support programs exclude foreign firms. Secondly, we have included indicators of the geographical location and the competitive environment. The study by Herrera and Nieto (2008) shows that the final result of subsidies changes in accordance with the location of the firm. A dummy variable took the value of one if the firm was located in a central region of the Spanish Innovation System (that is; Madrid, Catalonia, the Basque Country and Navarre, regions accounting for 70% of the country's R&D activity) and zero in the opposite case. In this group of variables we also included propensity to export (ratio between exports and sales multiplied by a hundred) and the sector of activity. In the latter case, we included three dummy variables that indicate whether the firm belongs to: a hi-tech manufacturing sector, a medium-tech manufacturing sector or a hi-tech service sector. In addition, as studies have showed that indicators of previous R&D experience and receipt of public funding in the past have a strong influence on obtaining subsidies; we have included a dummy variable that took the value of one if the firm carried out continuous R&D activities during the three years prior to receiving the subsidies and another dummy variable that took the value of one if the firm obtained subsidies in the previous period.

In order to estimate the additionality effects on the innovation activity Y_i of subsidised firms, the expenditures on basic research, applied research and technological development were defined as a percentage of the total private R&D expenditures, while the economic returns were defined as the ratio between sales obtained from new products and the total sales of the firm multiplied by a hundred. Finally, the study included the private R&D intensity (ratio between private R&D expenditure and firm turnover, multiplied by a hundred) to compare the results with those obtained by previous studies.

5. Results and discussion

Table 2 shows the findings of the Probit model and the marginal effects estimated to analyse the firms' propensity to obtain R&D subsidies. In the four models the dependent variable took the value of one if the firm received subsidies and zero in the opposite case. In the general sample the findings indicate that recently established firms, belonging to hi-tech service sectors, with previous R&D experience and which have obtained public funding in the past, had the highest probability of obtaining R&D subsidies. The estimation of the marginal effects shows that the variables with the greatest impact on this propensity were: belonging to hi-tech service sectors and obtaining public funding in the past. A change in these variables, ceteris paribus, would increase this propensity by 20 and 57 percentage points, respectively. These findings reflect the present situation of the Spanish productive system and innovation policy. On the one hand, most R&D growth in Spain has been driven by service sector expansion, where there has been an annual 16% increase, compared to 7.9% in the industrial sector (OECD, 2007). Consequently, an interpretation can be made that a relationship exists between present R&D growth and the public funding received in this sector. On the other, there are recent studies which have detected that it is normal for Spanish firms to receive subsidies from more than one public funding source (Herrera, 2008) and that obtaining subsidies in the past has a positive influence on obtaining public funding in the future (González and Pazó, 2008).

The comparative analysis by size shows that three variables produce differences in the profile of subsidised firms: the ownership, the propensity to export and the sector of activity. Unlike small firms, large and medium-sized ones are more prone to obtain subsidies if they are private firms without foreign capital. The literature evaluating the distribution of R&D subsidies shows that public agencies tend to exclude firms with foreign capital not just in Spain (Busom, 2000) but also in other countries (Almus and Czarnitzki, 2003). Subsidiaries of foreign firms could benefit from the R&D activities obtained in another country because there is a greater degree of centralisation of R&D activities within multinational corporations (Veugelers, 1997). The study also shows that the propensity to export significantly increases the likelihood of obtaining subsidies in the group of large firms. In Spain these firms are more likely to undertake an internationalization process and some studies show that they could have an interest in obtaining public funding, since opening up to international markets gives rise to gains which reinforce the innovation process and would allow them to compete and remain in markets (Czarnitzki and Licht, 2006; González et al., 2005; Heijs, 2005). Finally, the study detected differences with regard to the sector of activity. Small and medium-sized firms are more likely to obtain subsidies for R&D if they belong to the hi-tech service sector and this propensity grows, ceteris paribus, by 17 and 37 percentage points, respectively. In the case of small firms this propensity is significantly reduced if the firm belongs to the high-to-medium tech manufacturing sector. In accordance with an OECD report (2007), the design of the innovation policy in Spain is determined to a great extent by the country's industrial structure, principally made up of SMEs in traditional sectors, with a small number of firms specialising in high technology. Thus, one of the main challenges for the policymakers is to favour the expansion of hi-tech sectors and especially to support the vast majority of small firms which see no need to carry out innovation activities, or have insufficient organising capacity to take on research and development activities.

(Table 2 here)

Table 3 shows the findings of a means t-test carried out to compare the variables used in the matching process before and after the paring and to ensure the matching quality and robustness of the findings. As was to be expected, before matching, the analysis shows significant differences between the group of subsidised firms and the group receiving no subsidies. After the matching, these differences between the group of subsidised firms and the control group disappear.

(Table 3 here)

Table 4 shows the estimation of additionality effects. In the general model it is seen that subsidised firms increased their private R&D intensity compared to firms in the control group by 0.26 percentage points in the year when they received their subsidies and by 0.43 percentage points the year after. Although the magnitude of the effect is a modest one (German studies place it around 4 percentage points, (see Almus and Czarnitzki 2003), Spanish firms are not replacing private funds by public ones. There is a positive balance if it is borne in mind that the variable under analysis is constructed with the R&D expenditures financed by the firm with own funds and excluding other sources of finance. These findings coincide with previous studies in the Spanish case (see: Busom, 2000; Callejón and García-Quevedo, 2005; González and Pazó, 2008; González et al., 2005; Herrera and Heijs, 2007). This study also shows that subsidies had additionality effects on how firms have distributed their in-house R&D expenditures. In the year when firms received public funding they reduced their investment in basic research by a significant amount (-2.90 percentage points) and increased investment in applied research (3.51 percentage points) and technological development (5.01 percentage points). A year later, subsidised firms increased investment only in technological development (4.95 percentage points). In general, these results indicate that subsidised firms reduced their effort devoted to extending the frontier of technological knowledge (outside the technological core domain) and increased investments aimed at the generation of knowledge that provides immediate solutions to critical problems and those affecting the core area of business. The analysis also shows that subsidised firms increased the economic returns from the sale of products new to the firm in the period after they received the subsidies.

According to firm size, we also detect differences in the additionality effects produced by subsidies. The year in which firms received public funding saw no significant effect on the private R&D intensity. Nevertheless, a year later, this variable rose significantly only in the case of small and medium-sized firms (0.99 and 0.32 percentage points, respectively). In this study we used a means t-test to discover whether the effect was noticeably greater in one group of firms or another. The test indicates that there are no significant differences in the magnitude of these effects.

The results of the study confirm hypothesis 1. Subsidies have input additionality effects on the allocation firms made in their R&D expenditures and that impact changes with firm size. In relation to investments in basic research, the study shows that the effect of subsidies was negative and significant only for medium-sized firms (-6.01 percentage points). In no case of the present analysis did subsidised firms increase investments geared to extending the frontier of technological knowledge, which would have allowed them to diversify risk and combine related technologies in a complex manner to create a sustainable competitive advantage in the future. Nonetheless, the subsidies policy made it possible for medium-sized and small firms to increase their investments in applied research, the aim of which is to extend the knowledge base in the firm’s technological domain. In the year in which the subsidies were received these investments showed a significant rise in the case of medium-sized firms (8.52

percentage points), and a year later for small firms (6.12 percentage points). As can be observed, there is a substitution effect for investments in the case of medium-sized firms reducing their investments in basic research and increasing them in applied research. According to Rafferty (2003), R&D activities are related to the firm's business cycle and growth. For example, during expansion processes firms cut investment in basic research and increase investment in applied research and technological development, so that substitution effects might arise between different types of R&D, since these activities compete for resources (Henard and McFadyen, 2006). The study also shows that investments in technological development experienced a significant rise in small and large firms (9.37 percentage points and 8.43 percentage points, respectively), though there are no significant differences in the magnitude of the effect. A year later only small firms were still investing in this activity.

Table 4 also shows significant differences between economic returns and the degree of novelty of innovations of subsidised compared to non-subsidised firms in the control group, so hypothesis 2 is proved correct. Small firms showed an increase of 3.73 percentage points in the sale of products new for the firm during the period 2004-2006, even though their R&D effort was significantly higher than that of large firms. Small subsidised firms managed to materialize technological knowledge generated in incremental innovations which could guarantee success for them in the short term but not enable them to keep up their competitive advantage in the future. However, large firms were able to increase the sale of products new for the market, as a result, among other factors, of making a significant increase in technological development investments. The increase showed was of 5.36 and y 6.88, respectively in the two periods analyzed.

(Table 4 here)

6. Conclusions and policy implications

This study analysed the additionality effects of R&D subsidies on the way firms allocate their in-house R&D expenditures on basic research, applied research and technological development activities and on the economic returns of innovation process. These effects were estimated by comparing the innovative activity of firms receiving R&D subsidies and those not receiving them but who were more inclined to obtain them (control group). The study included a comparative analysis of these effects according to firm size.

In order to obtain a clearer estimation of the additionality effects a first part of the analysis has obliged us to bear in mind the allocation of R&D subsidies. In this previous analysis, we found that there are differences in the profile of subsidised firms regarding their size. For example, large firms are more likely to be subsidised if they are private firms without foreign capital and a high propensity to export, whereas in the case of small firms the determining aspect is their belonging to the hi-tech service sector. Though the literature has provided an explanation for some of these findings, we found that a priori these differences might not be enough to explain disparities in the magnitude of the effect of subsidies on these groups of firms. The above can be deduced from the results obtained in the study, which, regardless of size, shows that firms which are more likely to be subsidised were those with previous R&D experience who had obtained public funding in the past. The importance of these variables increases with firm's size, and reaches very high levels. For example, obtaining public funding in the past could, ceteris paribus, increase the likelihood of obtaining subsidies by more than 50 percentage points. Thus it is worthwhile considering that this approach in distribution reflects a certain isolation from the specific needs and problems that firms suffer as a result of their size. Moreover, continuous support for innovative firms would only contribute to improving funding of R&D activities in the case of firms which have shown their innovation capacity in the past, to the detriment of firms which wish to set in motion innovative projects for the first time.

In the second part of the analysis directed to estimating the additionality effects, we found three differences between subsidised firms compared to non-subsidised firms in the control group. First, we found that R&D subsidies were most effective in stimulating the private R&D intensity of small and medium-sized firms (input additionality). In general, these firms have more financial difficulties than large firms when taking on innovation activities and public funding has a positive complementary effect on private funding. Second, the study also showed that subsidies have effects on the way in which firms distribute their R&D expenditures on basic research, applied research and technological development activities. All of these activities are geared to increasing the firm's stock of technological knowledge. We found for all analysed cases, that subsidies did not encourage activities geared towards expanding the technological knowledge frontier (i.e. basic research) but managed to increase investments geared to extending the knowledge base in the firm's technological domain (i.e. applied research and technological development). On the other hand, investments in applied research and technological development would enable firms to put distance between themselves and their competitors in the short term. In this study we also found a particular substitution effect on investments in the case of medium-sized firms. These firms reduced investments in basic research and increased them in applied research. The findings of this study reveal, on the one hand, that large, medium-sized and small firms have different aims in their R&D activities when they request subsidies and, on the other, that the policy of subsidies may have an influence on how wide and how deep the firm's stock of technological knowledge is.

The third difference between subsidised and non-subsidised firms occurs in the economic returns of the innovation process (output additionality). The study found that only large and small subsidised firms increased their economic returns compared to firms receiving no subsidy. Nonetheless, the study shows that there is a different result if we take into account the degree of novelty of product innovations. In the case of small firms, albeit they increased their private R&D effort and investments in applied research and technological development, they only succeeded in increasing the sale of products new for the firm. This could be interpreted as showing that these firms are receiving subsidies to extend their technological knowledge base, but merely manage to materialise knowledge in an incremental innovation which may produce fruits in the short term, but which will hinder them in maintaining a future competitive advantage. Subsidised small and medium-sized firms, which provide the greatest economic value for the Spanish economy, are not obtaining new innovative products for the market. Fernández-Ribas and Catalán (2010) have already pointed out that this effect can become a limiting factor for medium-term development, since the springing up of new industries based on destructive innovations is restricted. The research will thus have to continue and managers and policymakers will have to work on the early detection of innovations which can potentially initiate a radical change in the industry. New policies could be created based on deeper knowledge of how these innovations occur and thus support the early stages of its development. In the case of large firms they obtained economic returns from innovations new for the market. The study shows that these firms only invested in technological development activities, rather than activities geared to extending the frontier of knowledge beyond the firm's technological domain. Consequently, large firms may have asked for public funding to support the process of transforming their stock of knowledge into new products and services for the market, since this is a critical phase of their innovation process.

The results of this study may have implications for policymakers if we take into account that granting aid in the past has a significant determination on obtaining public funding in the future. As a consequence of these decisions, policymakers should reflect on the role of innovation policy in the technological change process and the configuration of industry. We should not forget that the process involving the distribution of public funding implies, in turn, that public agencies take decisions about what aspects of innovation activity and technological change are to be stimulated to the detriment of others. As in the case of small firms, the present subsidy distribution approach could allow the continuation of a certain strategic behaviour which specialises in leading the firm towards a quest for immediate results rather than constructing a sustainable competitive advantage.

It must be pointed out that this study contains a series of limitations. For example, the survey has the limitation of only indicating where the subsidies come from (regional or national agencies) without giving details of the support program. As a result, the evaluation presented in this paper is general and the findings have to be interpreted by taking into account the characteristics of the data used and the case study. Another limitation is related to the method, which does not enable a longitudinal analysis to be made; consequently the effects that are not detected on the time horizon of our research might underestimate the impact of public incentives. Most likely, in some cases a more extensive time period may be needed for the effects of these subsidies to become visible in some of the variables or groups of firms. In addition, we are not able to control the time lag from the initiation of the innovation process up to the point results becomes visible. Finally, future research will find it necessary to increase the number of variables of interest to analyse the impact of these R&D subsidies on other aspects of firms' strategic behaviour such as: acquiring outside technology, contracting human resources and organisational behaviour.

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Table 1.
Studies regarding the innovation policy effect according to firm size.

Author	Country	Time Period	Method	Size	Results
Carmichael (1981)	United States	1976-1978	OLS	Large firms[a]	Substitutability
				Small firms[a]	Substitutability
Klette and Moen (1998)	Norway	1982-1995	OLS FE	Large firms > 263 employees	Complementarity
				Small firms < 58 employees	Not significant
Lach (2002)	Israel	1990-1995	DID	Large firms > 300 employees	Not significant
				Small firms < 300 employees	Not significant
Gonzalez et al., (2005)	Spain	1990-1999	Tobit	Large firms > 200 employees	Complementarity
				Small firms ≤ 200 employees	Complementarity
Gonzales and Pazó (2008)	Spain	1990-1999	ME	Large firms > 200 employees	Not significant
				Small firms ≤ 200 employees	Complementarity

OLS= Ordinary least squares; FE= Fixed effects; DID= Difference in Difference estimator
GLS= General least squares; ME= Matching estimator.
[a]= Information regarding group limits according to number of employees is not available.

Table 2.
Results of the Probit model estimations and marginal effects.

	General Model		**Small Firms**		**Medium sized firms**		**Large firms**	
	Coef.	**M.E**	**Coef.**	**M.E**	**Coef.**	**M.E**	**Coef.**	**M.E.**
Dependent variable = 1 indicates that the firms obtained R&D subsidies								
Firm Size (log number of employees)	-0.02		-0.06		-0.04		0.08	
Recently set-up firm dummy t-1	0.25*	0.08*	0.20		0.49		0.34	
Domestic and private firm dummy t-1	0.09		-0.21		0.22*	0.05*	0.31***	0.06**
Export propensity t-1 (%)	0.00		-0.00		-0.00		0.01***	0.00***
Firm location in a central region dummy t-1[a]	-0.02		-0.08		-0.03		0.12	
High-tech manufacturing sector dummy	0.05		-0.02		0.05		0.09	
Med-tech manufacturing sector dummy	-0.08		-0.22**	-0.07***	-0.10		0.16	
High-tech service sector dummy	0.60***	0.20***	0.45***	0.17***	1.10***	0.37***	0.01	
Previous R&D activity dummy t-3	0.33***	0.08***	0.25***	0.08***	0.31**	0.07***	0.45***	0.09***
Public funding dummy t-1	1.76***	0.57***	1.48***	0.51***	1.95***	0.61***	2.02***	0.62***
Number of firms	4713		1971		1543		1199	
Number of subsidised firms	1218		640		344		234	
Log Likelihood	-1791.83		-906.84		-497.38		-348.02	
Pseudo R^2	0.33		0.27		0.39		0.41	
Correctly classified (%)	84.94		80.00		87.75		90.08	

***significant at 1percent; ** significant at 5 percent; * significant at 10 percent.

M.E.= Marginal Effects

[a] Firms located in Madrid, Catalonia, Navarre and Basque Country.

Table 3.
Means comparisons between subsidised firms and non-subsidised firms (before matching) and between subsidised firms and control group (after matching)

	General model			Small firms			Medium sized firms			Large firms		
	S=1[a]	**Controls[b]**	**S=0**	**S=1**	**Controls**	**S=0**	**S=1**	**Controls**	**S=0**	**S=1**	**Controls**	**S=0**
Propensity score	0.30	0.30	0.16***	0.54	0.53	0.22***	0.51	0.50	0.12	0.47	0.46	0.10***
Private R&D expenditures t-1	89.57	89.73	70.38***	83.00	83.54	84.01	85.13	86.7**	75.58***	58.74	60.78	44.90***
High-tech manufac. sector dummy	0.05	0.05	0.08**	0.09	0.09	0.11	0.09	0.09	0.08*	0.11	0.11	0.06***
Med-tech manufac. sector dummy	0.13	0.13	0.27***	0.17	0.17	0.30***	0.24	0.24	0.30**	0.24	0.24	0,17***
High-tech service sector dummy	0.5	0.5	0.02***	0.14	0.14	0.03***	0.11	0.06***	0.01***	0.03	0.03	0.01***
Public funding dummy t-1	0.33	0.33	0.17***	0.73	0.73	0.18***	0.68	0.68	0.10***	0.58	0.58	0.06***

Significances (***significant at 1percent; ** significant at 5percent; * significant at 10 percent) indicate that the means compared differ according to the two tailed t-test.

[a] S=1 indicates that the firms obtained R&D subsidies and 0 in the opposite case

[b] Controls= means of firms in the control group

Table 4.
Average effect of the R&D subsidies on the firm's innovation activity

	General model Coefficients		**Small firms Coefficients**		**Medium sized firms Coefficients**		**Large firms Coefficients**	
	t	**t+1**	**t**	**t+1**	**t**	**t+1**	**t**	**t+1**
Inputs								
Private R&D intensity	0.26*	0.43***	0.07	0.99**	0.21	0.32**	0.01	-0.02
Basic research	-2.90**	-0.67	-1.72	-1.07	-6.01**	2.33	0.46	-0.55
Applied research	3.51*	3.03	2.28	6.12**	8.52**	0.61	-4.14	-3.57
Technological development	5.01**	4.95**	9.37***	7.64**	-1.29	-1.72	8.43*	8.02
Outputs								
% Sales of products new for firm	1.31	2.57*	3.73**	1.32	-3.26	1.18	-1.75	0.82
% Sales of products new for market	0.42	0.58	-2.98	-0.36	2.63	-1.59	5.36**	6.88**
Number of observations	4713		1971		1543		1199	
Number of observations with subsidies	1218		640		344		234	

***significant at 1percent; ** significant at 5percent; * significant at 10 percent.