The Impact of Intramural, Contracted R&D and Import of technology on the innovation returns of Spanish SMEs†

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Abstract

The aim of this study is to ascertain the impact of three different innovation strategies – namely, intramural R&D, externally contracted R&D, and import of technology through licenses- upon the returns to R&D (in terms of productivity) attained by small and medium-sized enterprises (SMEs) in the Spanish industry. This paper attempts to contribute to the current literature measuring the effects of innovation strategies on SMEs performance, which has yielded mixed and inconclusive results. In order to evaluate these effects we consider in a first step robust estimates of total factor productivity (TFP) through a GMM approach and numerically compute the sample distribution of the R&D returns. In a second step, we use a regression analysis approach to make inferences about the role of these innovation strategies and their combinations in shaping the distribution of the R&D returns. Also, we aim to analyse the effects of these innovation strategies in relation to the industry where the SME operates.

The data used in the analysis are drawn from the *Encuesta de Estrategias Empresariales* (ESEE). This is an annual survey sponsored by the Spanish Ministry of Industry and carried out since 1990 that is representative of Spanish manufacturing firms classified by industrial sectors and size categories. Using an unbalanced panel of a sample of Spanish manufacturing SMEs, i.e. companies with 10 to 200 employees, over the period 1990-2005, our results suggest that the innovation strategy that combines intramural and externally contracted R&D is the one that pays off more in terms of returns to R&D, while the import of technology seems not providing any additional sinergy effect, except for low-tech SMEs. In the case of low-tech SMEs, the import of technology appears complementary of externally contracted R&D. These results suggest that government policies should stimulate both in-house and externally contracted R&D, and focus on the particular synergy effects between these two strategies. Additionally, in the case of low-tech sectors, the role of imported technology should also be taken into consideration.

Key words: intramural R&D, contracted R&D, import of technology, R&D returns, TFP, SMEs.

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1. Introduction.

It is acknowledged that R&D is an important determinant of firm's productivity, innovation and competitiveness (Griliches, 1980). Since small and medium-sized enterprises (SMEs) play an increasingly important role in the Spanish economy (accounting for over 78% of employment and 68% of value added, Eurostat (2005)), it is desirable that SMEs are stimulated into the adoption and generation of innovations. However, it must be realized that not all innovations employed within a firm are induced by the firm through its own R&D: many innovations are purchased through technological licensing or in the form of externally contracted industrial research, and firms may introduce different combinations of these alternatives in order to shape their own innovation strategy. The aim of our study is to analyse the impact of different innovation strategies –defined as intramural R&D; externally contracted R&D; and, imports of technology - and their combinations upon the private return to R&D (in terms of total factor productivity, TFP). This paper attempts to contribute to the current literature measuring the effects of innovation strategies on SMEs performance, which has yielded mixed and inconclusive results.

More specifically, we seek to analyze the effects of three different innovation strategies and their combinations on the contribution of R&D to firm's productivity in Spanish manufacturing SMEs using recent methodological innovations. In particular, we follow a two-step strategy. In the first step, we use a GMM approach to consistently estimate the input coefficients of a Cobb-Douglas production function under the assumption that firms' expectations on future productivity depend on their current productivity as well as on their current R&D spending (Doraszelski and Jaumandreu, 2009). We also obtain estimates of the firm's (non-observable) productivity, which we use to compute the sample distribution of the private R&D returns using a numerical approximation (Judd, 1998). In the second step, we use a regression analysis approach to make inferences about the role of these strategies and their combinations in shaping the distribution of the R&D returns. Also, we aim to analyse the effects of these technological strategies in relation to the industry where the SME operates. The analysis is performed for an unbalanced panel of Spanish manufacturing SMEs drawn from the "*Encuesta Sobre Estrategias Empresariales*" (ESEE) and observed for the period 1990-2005.

Previous studies analysing the role of innovation strategies on firm's innovation performance have produced mixed findings, and have largely ignored SMEs as a research population. For instance, Cassiman and Veugelers (2006) in a study of Belgian firms found that internal R&D and external knowledge acquisition were complementary with respect to influencing innovation performance. In contrast, Laursen and Salter (2006) found evidence of a substitution effect between internal R&D and external knowledge sourcing strategies. Our study provides new empirical evidence on the effect of internal and external knowledge sourcing strategies adopted by Spanish manufacturing SMEs, on innovation performance. Our study differs from previous studies on several aspects: First, instead of focusing on large firms we explore the role of innovation strategies in SMEs, traditionally characterized by limited R&D investment. Secondly, instead of relying on cross-sectional data (e.g. Cassiman and Veugelers, 2006), we explore a panel data set to examine these effects at firm level (see also Lokshin *et al.*, 2008). Thirddly, instead of looking at the correlation (or adoption) structure between internal and external sources of innovation[1], we examine the performance effect of

[1] This approach has been shown to suffer from measurement problems and inference difficulties (Arora, 1996; Piga and Vivarelli, 2004).

three kinds of innovation-related strategies: the decision to conduct R&D internally; the decision to contract R&D externally; and the decision to acquire foreign technology through licensing, plus all the combinations between these strategies. Thus, extending previous studies (see Cassiman and Veugelers, 2006; Vega Jurado *et al.*, 2009), we investigate the effects of intramural R&D and two strategies for acquiring external knowledge (contracted external R&D and import of technology).

Our results reveal that the technological strategy that combines *Internal and external R&D* is the one that pays off more in terms or returns to R&D to SMEs; however, combining any strategy with *Imported technology* does not make any improvement in the returns to R&D, except for low-tech SMEs. By technological intensity breakdown we confirm these results although the size of the increase in the returns to R&D for the strategy *Internal and external R&D* vary across sectors. Therefore, it seems that there are complementary effects between undertaking *Internal R&D* and *External R&D* in Spanish manufacturing SMEs.

The remainder of this paper is organized as follows. The next section reviews previous empirical studies on the relationship between internal and external sources of knowledge and their impact on firm's perfomance. In section 3 we present the empirical model and discuss the estimation methodology. Section 4 describes the data and section 5 presents the empirical results. Section 6 concludes.

2. Literature review.

The distinction between internal and external sources of knowledge and the analysis of its various impacts on the returns to innovation has attracted great interest both theoretically and empirically. This trend of the literature is partly explained by the accelerating process in the use of external sources of knowledge that has been accompanied, in parallel, by a reduction of the presence of internal R&D departments (Narula, 2001; Bönte, 2003). However, the empirical evidence on the potential complementarities between these strategies and their differential impact on firm's innovation performance is still inconclusive.

As regards the theoretical literature, there are both studies indicating the importance of external sources of knowledge in the innovation process (Chesbrough, 2003), and studies that argue that, in certain industries, the company's internal resources are the main drivers of the firm's returns to innovation (Freel, 2003). Besides, arguments in line with the transaction costs theory would suggest that the acquisition of external knowledge may substitute for intramural R&D (Williamson, 1985). From a more inclusive perspective, there are studies which point out that internal and external knowledge acquisition may be complementary strategies in the innovation process. These studies argue that the firm's internal sources of knowledge not only generate new knowledge, but at the same time they increase the firm's ability to exploit the external sources in the development of new products and processes. This is evocative of the notion of "absorptive capacity" (Cohen and Levinthal, 1989), which stresses the importance of internal knowledge to effectively absorb external know-how.

While there is an increasing number of empirical evidence on the impact of the internal and external innovation strategies on innovative outcomes (Veugelers and Cassiman, 2006, and later references that have followed this strand), most empirical works devoted to this analysis do not distinguish among different types of external strategies available to the firm[2] – as it is the distinction between externally contracted R&D and acquisition of foreign technology through licensing.[3]

Nevertheless, independently of the external innovation strategy used in the analysis, the empirical evidence on the complementarity in innovation performance between internal and external innovation strategies provides mixed findings. For instance, Cassiman and Veugelers (2006) find that intramural R&D and external knowledge acquisition are complementary in influencing innovation performance in Belgian firms. In the same line, Lokshin *et al.* (2008), using a dynamic panel of Dutch manufacturing firms, find also complementarities between the two strategies, but external R&D has only a positive impact on innovation performance in case of sufficient internal R&D. In contrast, Laursen and Salter (2006), for a sample of UK firms, find evidence of a substitution effect between internal R&D and external knowledge sourcing strategies. Similarly, Kraft (2006), analysing whether firm's R&D intensity and its R&D cooperations are complementary in terms of innovative performance, interpret their findings as a hint towards a rather substitutive relationship. On the other hand, the results by Schiemdeberg (2008) provide evidence for significant complementarities between internal R&D and R&D cooperation in German manufacturing firms, but cast doubt on the complementarity of internal and contracted R&D.

[2] There are few exceptions, as it is the case of the study on Spanish firms of Vega-Jurado et al. (2009) that distinguish between external knowledge acquisition and cooperation as two different external innovation strategies. See also Laursen and Salter (2006) and Schiemdeberg (2008).

[3] In the literature we can find studies that analyse the complementriety between internal R&D and imports of technology (Lee, 1996; Katrack, 1997). However, these studies tend to focus on developing economies, with rather few studies using data for develop economies (for instance, González Cedeira et al., 1999).

Regarding the empirical evidence for Spanish manufacturing firms there are also mixed results. On one hand, Beneito (2006) finds a positive effect of externally contracted R&D when combined with internal R&D, pointing out the role of absorptive capacity. Based on the distinction between innovation types measured by patents and utility models, Beneito stresses a particular aspect of complementarity concluding that internal R&D produces rather significant innovation whereas contracted R&D seems more orientated towards innovations of incremental nature. In the same line, Cruz-Cázares *et al.* (2010), analysing the different effect of R&D strategies upon innovation outputs, find that internal, external R&D and the combination of both strategies have a different impact on performance, with the combined strategy having the greatest impact (a sign of complementarity) and the external-only strategy having the lowest. The study by Vega-Jurado *et al.* (2009) confirms also the different impact of innovation strategies; in this case upon different innovation types (process and product), but in contrast to the previous studies, they are unable to find complementarities between internal and external sources.

By and large, these various strands of the empirical literature indicate the inconclusive nature on the debate between the different impact of innovation strategies and the complementarity between them in shaping firms' innovative performance.

3. Empirical strategy.

We assume that firms produce a homogenous good using a Cobb-Douglas technology:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \beta_m m_{it} + \omega_{it} + \eta_{it} \quad (1)$$

where y_{it} is the natural log of production of firm i at time t, l_{it} is the natural log of labour, k_{it} is the natural log of capital, a_{it} is the natural log of age of the firm and, m_{it} is the natural log of intermediate inputs. As for the unobservables, ω_{it} is the productivity (not observed by the econometrician but observable -or predictable by firms) and η_{it} is the productivity news that is neither observed nor predictable by the firm.

It is also assumed that age and capital evolve following a certain law of motion that is not directly related to current productivity shocks (i.e. they are state variables), whereas labour and intermediate materials are inputs that can easily be adjusted whenever the firm faces a productivity shock (i.e. they are variable factors).

Following Wooldridge (2009) GMM estimation approach, both Olley and Pakes (1996)(OP, hereafter) and Levinshon and Petrin (2003) (LP, hereafter) estimation methods can be considered as consisting of two equations: the first equation tackles the problem of endogeneity of the non-dynamic inputs; and the second equation deals with the issue of the law of motion of productivity.

Let us start considering first the problem of endogeneity of the non-dynamic inputs. Correlation between variable inputs and productivity complicates the estimation of equation (1), for it makes the OLS estimator biased and the fixed-effects and instrumental variables methods generally unreliable (Ackerberg et al., 2007). Both OP and LP use a proxy (control) function approach to solve this problem based on using the investments and materials, respectively, to proxy for the "unobserved" firm productivity.

OP assumes that the demand of investment, $i_{it} = i_t\left(k_{it}, a_{it}, \omega_{it}\right)$, is a function of capital, age and productivity. LP to circumvent the problem of firms with zero investments uses the demand of materials ($i_{it} = i_t\left(k_{it}, a_{it}, \omega_{it}\right)$) instead as proxy variable, and this is the approach that we will follow in our analysis. [4]

Therefore, when estimating productivity using these general versions of OP and LP in a sample with R&D performers and non-performers, it is assumed identical demand of investments/demand of intermediate materials for both groups of firms.

However, as it is possible to see in Table 3, R&D performers differ in many aspects from non-performers. Thus, we aim at considering different demands of intermediate inputs for R&D performers and non-performers, i.e. we will allow the intermediate inputs demand to depend on R&D experience. Thus, we write the demand of materials as:

$$m_{it} = m_R\left(k_{it}, a_{it}, \omega_{it}\right) \quad (2)$$

where we include the subscript *R* to allow for different demands of intermediate inputs for R&D performers and non-performers. Then, given that the demand of intermediate inputs is assumed to be monotonic in productivity it can be inverted to generate the following inverse demand function of materials:

$$m_{it} = m_R\left(k_{it}, a_{it}, \omega_{it}\right) \quad (3)$$

where h_R is an unknown function of *k*, *a*, and *m.*

Then, substituting (3) into the production function (1) we get:

[4] Both the investment demand function and the demand of intermediate inputs are assumed to be strictly increasing in ω_{it} (in the case of investment in the region in which i_{it}>0). That is, conditional on k_{it} and a_{it} a firm with higher ω_{it} optimally invests more (it demands more intermediate inputs).

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \beta_m m_{it} + h_R\left(k_{it}, m_{it}, a_{it}\right) + \eta_{it} \qquad (4)$$

and after taking into account in (4) both that we cannot identify β_k, β_m and β_a and that we consider to different demands of intermediate inputs for R&D performers and non-performers, our first estimation equation is given by:

$$y_{it} = \beta_l l_{it} + 1\left(non\_perf\right)H_0\left(k_{it}, a_{it}, m_{it}\right) + 1\left(perf\right)H_1\left(k_{it}, a_{it}, m_{it}, R_{it}\right) + \eta_{it} \qquad (5)$$

where 1(*non-perf*) and 1(*perf*) are indicator functions that take the value of 1 for non-performers and R&D performers, respectively, while R_{it} represent the firm's expenditure in R&D. Further, the unknown functions H_0 and H_1 are proxied by third degree polynomials in their respective arguments.

The second estimation equation deals with the law of motion of productivity. The standard OP/LP approach neglects the possibility of previous R&D experience to affect productivity as they consider that productivity evolves according to an exogenous Markov process:

$$\omega_{it} = E\left[\omega_{it} \middle| \omega_{it-1}\right] + \xi_{it} = f(\omega_{it-1}) + \xi_{it} \qquad (6)$$

where f is an unknown function that relates productivity in t with productivity in t-1 and ξ_{it} is an innovation term uncorrelated by definition with k_{it} and a_{it}.

A solution is to consider a more general process (endogenous Markov process) in which previous R&D experience can influence the dynamics of productivity (see Doraszelski and Jaumandreu, 2009):

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \beta_m m_{it} + h_R\left(k_{it}, m_{it}, a_{it}\right) + \eta_{it} \qquad (7)$$

where R_{it-1} is a vector of variables summarising a firm R&D experience.

Let us now to rewrite the production function (1) using (7) as:

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \beta_m m_{it} + h_R\left(k_{it}, m_{it}, a_{it}\right) + \eta_{it} \tag{8}$$

Further, since $\omega_{it} = h_R\left(k_{it}, a_{it}, m_{it}\right)$ and we consider different demands of intermediate inputs for R&D performers and non-performers, we can rewrite $f(\omega_{it-1}, R_{it-1})$ as:

$$\begin{aligned} f(\omega_{it-1}, R_{it-1}) &= f\left[h_R\left(k_{it-1}, a_{it-1}, m_{it-1}\right), R_{it-1}\right] = F_R\left(k_{it-1}, a_{it-1}, m_{it-1}\right) = \\ &= 1\left(non\_perf\right) F_0\left(k_{it-1}, a_{it-1}, m_{it-1}\right) + 1\left(perf\right) F_1\left(k_{it-1}, a_{it-1}, m_{it-1}, R_{it-1}\right) \end{aligned} \tag{9}$$

Thus, substituting (9) in (8), our second estimation equation is given by:

$$\begin{aligned} y_{it} &= \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \beta_m m_{it} + 1\left(non\_perf\right) F_0\left(k_{it-1}, a_{it-1}, m_{it-1}\right) + \\ &+ 1\left(perf\right) F_0\left(k_{it-1}, a_{it-1}, m_{it-1}, R_{it-1}\right) + u_{it} \end{aligned} \tag{10}$$

where $u_{it} = \eta_{it} + \xi_{it}$ is a composed error term and the unknown functions F_0 and F_1 are proxied by third degree polynomials in their respective arguments.

Wooldridge (2009) proposes to estimate jointly equations (5) and (10) by GMM using the appropriate instruments for each equation. These joint estimation strategy has several advantages: i) it increases efficiency relative to two step traditional procedures (e.g. OP and LP); ii) it makes unnecessary to bootstrap to calculate standard errors; and iii) it solves the problem of identification of the labour coefficient in the estimation of equation (5) pointed out by Ackerberg *et al* (2006).

The downside is that since R&D does not enter directly in the specification of the production function, we cannot estimate its marginal or partial effect with respect to the firms' output. However, we may compute the sample distribution of the (lagged) R&D returns using a numerical approximation to the derivative and the estimates of the firm's productivity (Judd, 1998). In particular, we use a three-point formula with a bandwidth parameter calculated using lagged R&D as the upper bound of the fourth derivative and trim 2.5% of observations at each tail of the distribution to avoid outliers.

In a second step, we pair-wise compare the returns to R&D of firms that undertake different innovation strategies. In particular, we test whether undertaking internal R&D versus external R&D only (or other strategies, such as external R&D plus imported technology through licenses or internal R&D combined with imported technology), reports significant higher returns to R&D for a firm. Analogously, we test whether undertaking external R&D versus undertaking external R&D combined with importing technology, implies higher returns to R&D. Finally, we also consider the comparison of undertaking both internal and externally contracted R&D versus externally contracted R&D, and the combination of the three strategies (internal R&D, externally contracted R&D and imported technology) versus external R&D combined with imported technology. These pair-wise comparisons will allow establishing a ranking of the best innovation strategy (among the distinct combination of strategies) for SMEs, in terms of the returns to R&D.

To do all these comparisons we relate the estimated returns to R&D to relevant indicators for the different technological strategies and several control variables (log (size), year dummies, fixed effects). Specifically, to investigate the role of the distinct technological strategies on returns to R&D we estimate the following equation:

$$\log rRD_{it} = \beta_0 + \beta_1 s[1,0,0]_{it} + \beta_2 s[1,1,0]_{it} + \beta_3 s[1,0,1]_{it} + \beta_4 s[0,1,1]_{it} + \beta_5 s[1,1,1]_{it} + control_{it} + \alpha_i + e_{it} \quad (11)$$

where the dependent variable, rRD_{it}, is the return to R&D by firm i in period t, $s[1,0,0]_{it}$ is an indicator for firms whose strategy is *Internal R&D only*, $s[1,1,0]_{it}$ indicates that the firm's strategy is a combination of *Internal and external R&D*, $s[1,0,1]_{it}$ indicates that the strategy is *Internal R&D* and *Imported technology,* $s[0,1,1]_{it}$ indicates that the strategy is *Externally contracted R&D* and *Imported technology,* and, finally, $s[1,1,1]_{it}$ indicates the strategy combines *Internal, externally contracted R&D*, plus *Imported technology.*[5] In the *control* variable we account for size and year dummies. We estimate equation (11) using a fixed effects model.

On the basis of the estimated coefficients from equation (11) we will pair-wise test one strategy against another one.

4. The data.

To conduct our research we use a representative sample of Spanish SME manufacturing firms drawn from the *Encuesta sobre Estrategias Empresariales* (ESEE) for the period 1990-2005. This is an annual survey sponsored by the Spanish Ministry of Industry and carried out since 1990 that is representative of Spanish manufacturing firms classified by industrial sectors and size categories. The sampling procedure of the ESEE is the following. Firms with less than 10 employees were excluded from the survey. Firms with 10 to 200 employees were randomly sampled, holding around 5% of the population in 1990. All firms with more than 200 employees were requested to

[5] The reference category is $s[0,1,0]_{it}$ that indicates that the firm's strategy is *External R&D only.*

participate, obtaining a participation rate of about 70% in 1990. Important efforts have been made to minimise attrition and to annually incorporate new firms with the same sampling criteria as in the base year, so that the sample of firms remains representative of the Spanish manufacturing sector over time. Firms in the ESEE correspond to 20 industrial sectors according to the 2-digit NACE classification for manufactures. For this study we have selected SME firms (firms with 10-200 workers).

We consider this survey is quite unique to develop this piece of research, as this is a general survey with very rich and detailed information on firm activities and strategies[6] continuously (real panel data). Further, it covers 15 years of Spanish manufacturing. Among the variables we find in the survey we can outline the following: complete information to construct a firm productivity index (TFP) using any firm level approach, very detailed information about firms' innovation activities (information on patents, utility models, product innovation and process innovation, information on internal and contracted (external) R&D expenditures, information on other informal innovation activities and expenditures (revenues) for paying (selling) licenses.[7] Thus, we can relate firm innovation profiles with a broad range of characteristics of firms (i.e., productivity, performance, returns to R&D, etc.) and their environment.

The sample of SME firms for this period consists of 2512 firms (18124 observations). However, our final sample is an unbalanced panel of 890 SME manufacturing firms (9849 observations) observed at least three consecutive years over the period 1990 to 2005, see Table 1. The panel is unbalanced due to the existence of missing observations in critical variables (see the appendix for definitions and data sources). In particular, to construct the final sample we selected firms that provided

[6] For example, innovation or export strategies pursued by firms.
[7] Further information about this survey can be found in the following web page, provided by FUNEP: http://www.funep.es/esee/en/einfo_que_es.asp.

information for three or more consecutive periods on output, capital, materials, age and number of workers on one hand and on the expenditures on the three innovation strategies considered (i.e., expenditure on internal R&D, on external R&D and on imported technology through licenses).

[Table 1 here]

In Table 2 we provide descriptive statistics of the technological strategies followed by the SMEs (internal R&D activities, externally contracted R&D activities or imports of technology through licenses), by technological intensity sector. We observe that 25% of the SMEs in our sample are involved in innovative activities (see Table 1).[8] With respect to the combination of R&D strategies, we observe that 36% of the SMEs only undertake internal activities and 33% of them combine internal and external R&D strategies. The combination of the three strategies is done by a 3% of the SMEs. We also have that 15% of the SMEs only undertake external R&D activities. Further, 8% of the SMEs only import technology through licensing, 3% combine internal R&D and import technology, and, finally, only 2% of the SMEs in our sample combine external R&D activities with the imports of technology.

By technological sector breakdown, it is interesting to underline some differences with the general pattern described above. We observe that 39% of the firms operating in the high-tech sector combine internal and external R&D strategies, whereas this figure is 30% and 33% for SMEs operating in the med and low-tech industries. As regards the strategy "only internal R&D", we observe that it is undertaken by 34% and 42% of the SMEs in the high and med-tech industries, and by 33% of SMEs

[8] We define innovative SMEs those declaring positive R&D expenditures (either in internal or externally contracted R&D activities) plus importers of technology through licensing, during at least one year of the observed period.

in the low-tech sector. Further, we observe that 7% of SMEs in the high-tech sector combine the three innovation strategies, while 3% firms in the med-tech sector do so and only 1% of SMEs in the low-tech sector combine the 3 strategies. The third different feature we observe is that only 9% of SMEs in the high-tech industries undertake external innovation activities, whereas 15% of SMEs in the med-tech and 21% in the low tech do so.

From the above descriptive statistics, we can conclude that the innovation strategies pursued by SMEs operating in different technological intensity sectors are quite different. In particular, we see that the higher the technological intensity of the sector the lower the probability of implementing an "internal and external" or the "internal and external, plus importing" technologies. Further, the lower the technological intensity of the sector the higher the probability of undertaking the "only external R&D" strategy.

[Table 2 here]

Next, we identify some stylized facts about SMEs performing innovation activities and SMEs that do not, using a simple regression analysis (see Table 3). The objective is to explore the relationship between performing R&D activities at the firm level and some basic firm characteristics. In particular, output per worker, capital per worker, materials per worker, age and size of the firm are the main characteristics we focus on. To be more specific, we estimate an equation of the form:

(4)

where the dependent variable is alternatively output per worker, capital per worker, materials per worker, age and size. The logit transformation of the dependent variable is introduced to deal with the fact that the dependent variables are proportions with values between 0 and 1. The variable drd_{it} is a dummy variable that takes on value 1 if the firm performs any kind of R&D activity (either internal, external or both). We also control for size (number of employees), industrial sector and year.

[Table 3 here]

The differences (in %) between R&D performers and non-performers, computed from the estimated coefficient β_1 as $100(\exp(\beta) - 1)$, show the average percentage difference in the five firm characteristics considered between R&D performers and non performers, controlling for size, industrial sector and year. In all cases, we obtain that there are significant differences between R&D performers and non-performers: output, capital and materials per worker are significantly bigger for R&D performers. Further, there are also significant and positive differences for age and size between the two groups of firms. These significant differences give support the approach undertaken in this piece of research as regards to endogenously consider the link between R&D and productivity.

5. Results.

Table 4 provides estimates of the production function (1) using alternative estimation methods: OLS, fixed effects, and GMM (with and without R&D in the Markov process that defines productivity, i.e. using the Wooldridge (2009) estimator with an Exogenous Markov Process and the simplified version of the Controlled Markov Process of Doraszelski and Jaumandreu (2009), respectively. Results are similar to those obtained in previous studies —see Hall *et al.* (2009). In particular, figures in Table 4 show that

OLS estimates tend to overestimate the effect of labour and underestimate that of capital.

[Table 4 here]

The main aim in this piece of research is to analyse the returns to R&D in SMEs (or more appropriately the TFP elasticities with respect to R&D). As discussed in the previous section, these are obtained by a numerical approximation method applied to the estimated productivity. However, it is worth noting that since the instruments employed to estimate productivity are two-period lags of some variables, we are able to compute the R&D elasticity distributions only for the last twelve years of the sample (1994-2005).

Prior to formally presenting the pair-wise tests, we present the results for the estimation of the returns to R&D equation (see table 5) obtained after estimating equation (11). In particular, we report the results for the whole sample (column 1) and the breakdown by technological sector (columns 2-4). In the equation estimated, the reference category strategy is *Externally contracted R&D only* (s[0,1,0]). Therefore, the results for the coefficients estimates are in relation to this category.

[Table 5 here]

From our findings, and focusing in the results for the whole sample (first column), we obtain that SMEs whose technological strategy is *Internal R&D only* (s[1,0,0]) have no significant higher return to R&D than the reference firms (those whose strategy is *Externally contracted R&D only*). However, SMEs whose innovation strategy combines *Internal and external R&D* (s[1,1,0]), enjoy a positive and significant higher return to R&D (about 3%) than the reference firm. This result is maintained for low and med-tech sectors, for which combining in-house and externally contracted R&D provides larger R&D returns (of the order of 5% or more). Moreover, those SMEs whose innovation strategy combines *Internal, external R&D and imported technology* (s[1,1,1]), also enjoy a positive and significant higher return to R&D (about 3.5%). Across technological sectors, we find that SMES in low and med-tech sectors that combine the tree innovation strategies are able to attain higher R&D returns (about 8% and 5% in the case of low and med-tech, respectively) than those firms using only externally contracted R&D.

On the basis of the estimated coefficients, the next step is to formally test whether any of the technological strategies pursued by SMEs dominates any of the other ones (see table 6). In particular, we test: (i) *Internal R&D only* versus *Externally contracted R&D only;* (ii) the combination of *Internal and externally contracted R&D* versus *Externally contracted R&D only;* (iii) the combination of *Internal and external R&D* versus *Internal R&D only;* (iv) the combination *External R&D and imported technology* versus *External R&D* only*;* (v) the combination of *Internal R&D and imported technology* versus *Internal R&D only*; and, (vi) *Internal and external R&D plus imported technology* versus *Internal and external R&D*. As before, we report the results for all firms and by technological intensity sectors.

[Table 6 here]

From our results, and focusing on the sample of all firms (first column of table 6), we conclude that combining both *Internal and externally contracted R&D* reports a significant increase in the firms' returns to R&D, in terms of productivity, vis-à-vis undertaking *Internal R&D only* or *Externally contracted R&D only*. In particular, when we compare the strategy that combines *Internal and externally contracted R&D* with the strategy *Externally contracted R&D only* the increase in the returns to R&D is 3.3% (and statistically significant); and, when we compare it with the strategy *Internal R&D only*, the increase in the returns to R&D is 3.1% (and statistically significant). These results point out to the existence of complementarities by doing both innovation strategies together. Further, when we conduct the analysis by technological intensity (see columns 3-4), we confirm the above results but we are able to offer some valuable insights. In particular, for low and med-tech sectors, in-house and externally contracted R&D appear complementary, as combining both strategies offers significantly higher returns than conducting each innovation strategy separately. Further, the incremental return to implementing the combined strategy is greater if externally contracted R&D is already implemented, than if internal R&D is implemented. In other words, in the case of low-tech the incremental return of combining both strategies is 5.4% (5.9% in med-tech) if externally contracted was already implemented, while it is 3.8% (4.3% in med-tech) if internal R&D was already implemented. This result provides further light into the important role of intramural R&D in SMEs.

Further, *Imported technology* only appears to have a significant role in low tech sectors, and only if *Externally-contracted R&D* has already been implemented. Particularly, the incremental return of combining *externally contracted R&D* and *Imported technology* if *Externally contracted R&D* is already implemented is 6.7%*, while* the incremental return of combining *internal*, *externally contracted R&D* and *Imported technology* if *In-house* and *Externally contracted R&D* are already implemented is 2.8%.

Therefore, we can conclude that: (i) independently of the sector, the superior strategy in terms of the increase in the returns to R&D is the combination of *Internal and external R&D*, with both strategies showing complentarity effects in the returns to innovate; and, (ii) combining these strategy with *Imported technology* does not make any improvement in the returns to R&D, with the exception of low tech firms where import of technology appears complementary of Externally contracted R&D.

6. Conclusions.

The latest SBS report (European Commission, 2011) shows that though Spanish SMEs are less likely to introduce innovation, collaborate or innovate in-house, those that innovate are more successful than their EU peers in converting these new products and processes into sales revenues. It is evidence like this that is behind the increasingly commitment of policymakers in Spain to supporting innovation is small and medium sized firms. However, for these policy initiatives to be successful, an understanding of the innovation process in SMEs and the different innovation strategies available to SMEs is required. Therefore, the aim of our study is to analyse the impact of different innovation strategies –defined as intramural R&D; externally contracted R&D; and, imports of technology - and their combinations upon the private return to R&D (in terms of total factor productivity, TFP). This paper attempts to contribute to the current literature measuring the effects of innovation strategies on firm performance, which has yielded mixed and inconclusive results. For that purpose we explore a Spanish panel data for manufacturing (ESEE) for the period 1990-2005.

Our results reveal that the technological strategy that combines *Internal and externally R&D* is the one that pays off more in terms or returns to R&D. Therefore, it seems that there are complementary effects between undertaking *Internal R&D* and *External R&D.* However, combining any strategy with *Imported technology* does not make any improvement in the returns to R&D, with the exception of low tech firms where import of technology appears complementary of Externally contracted R&D. These results suggest that government policies should stimulate both in-house and externally contracted R&D, and focus on the particular synergy effects between these two strategies. Additionally, in the case of low-tech sectors, the role of imported technology should also be taken into consideration.

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Table 1. Number of SME firms by technological intensity breakdown.

Firms	All firms		Low-tech		Med-tech		High-tech	
Total number of firms	1181		570		415		196	53%
Number of innovative firms	291	25%	92	16%	107	26%	92	47%

Notes:

1. Innovative firms are defined as those exhibiting positive R&D plus licensing during at least one year of the observed period.
2. The total sample of 1181 SMEs corresponds to 9849 observations, and the sample of the 291 SME innovative firms corresponds to 2196 observations.

Table 2. Technological strategies for the SME innovative firms.

Observations	**All firms**		**Low-tech**		**Med-tech**		**High-tech**	
Only internal R&D	798	36%	239	33%	331	42%	228	34%
Only external R&D	329	15%	150	21%	120	15%	59	9%
Only imports of technology	173	8%	64	9%	56	7%	53	8%
Internal and external	719	33%	220	30%	236	30%	263	39%
Internal and imports of technology	59	3%	24	3%	18	2%	17	3%
External and imports of technology	45	2%	22	3%	11	1%	12	2%
Internal external and imports of technology	73	3%	8	1%	21	3%	44	7%
Total	2196	100%	727	100%	793	100%	676	100%

Table 3. Differences between SME R&D performers and non performers.

	Difference in % (R&D performers vs. no performers)	Standard error	*p*-value
Output per worker	40.41	0.004	0.000
Capital per worker	47.56	0.059	0.000
Materials per worker	56.20	0.052	0.000
Age	7.6	0.041	0.073
Size	109.28	0.052	0.000

Notes: For the estimation of the differences in size across firms groups we do not include *log*(size) as a regressor.

Table 4. Product function estimates.

	OLS	**FE**	**GMM (exogenous Markov process)**	**GMM (endogenous Markov process)**
	(1)	**(2)**	**(3)**	**(4)**
Labour	0.265***	0.390***	0.214***	0.214***
	(0.012)	(0.017)	(0.003)	(0.003)
Materials	0.654***	0.484***	0.638***	0.633***
	(0.010)	(0.013)	(0.022)	(0.022)
Capital	0.091***	0.093***	0.082***	0.083***
	(0.005)	(0.008)	(0.015)	(0.015)
Age	0.033***	0.329***	0.073***	0.075***
	(0.005)	(0.013)	(0.059)	(0.060)

Notes:

1. The dependent variable is (log) value added.
2. Standard errors are in brackets.
3. ***, **, * denote level of significance at 1%, 5%, and 10%, respectively.

Table 5. Percentage of increase for the rate of return of R&D in terms of productivity.

	All sample	Low-tech	Med-tech	High-tech
Internal R&D	0.002	0.016	0.016	-0.008
	(0.008)	(0.011)	(0.001)	(0.016)
Internal and external R&D	0.033***	0.054***	0.059***	0.023
	(0.007)	(0.010)	(0.013)	(0.015)
Internal R&D and imported technology	0.011	0.018	0.006	-0.027
	(0.013)	(0.017)	(0.019)	(0.018)
External R&D and imported technology	-0.026	0.067***	0.006	-0.005
	(0.016)	(0.026)	(0.001)	(0.024)
Internal and external R&D and imported technology	0.035***	0.082***	0.054***	0.018
	(0.011)	(0.016)	(0.016)	(0001)
Log employment	0.050***	0.046***	0.001	0.093***
	(0.008)	(0.011)	(0.015)	(0.012)

Notes:

1. We estimate the returns to R&D equation controlling for fixed effects.
2. All estimations control for size and year dummies. Standard errors are in parenthesis.

Table 6. Comparing the increase in the rate of returns of R&D in terms of productivity between different innovation strategies.

	All sample	Low-tech	Med-tech	High-tech
Comparing internal R&D only versus external R&D only				
	0.002	0.016	0.016	-0.008
	(0.008)	(0.011)	(0.014)	(0.016)
Comparing internal and external R&D versus external R&D only				
	0.033***	0.054***	0.059***	0.023
	(0.007)	(0.010)	(0.013)	(0.015)
Comparing internal and external R&D versus internal R&D only				
	0.031***	0.038***	0.043***	0.031***
	(0.004)	(0.006)	(0.007)	(0.007)
Comparing external R&D and imports of technology versus external R&D				
	-0.026	0.067***	0.006	-0.005
	(0.017)	(0.026)	(0.022)	(0.024)
Comparing internal R&D and imports of technology versus internal R&D				
	0.008	0.002	-0.010	-0.019
	(0.012)	(0.014)	(0.015)	(0.012)
Comparing internal and external R&D plus imports of technology versus internal and external R&D				
	0.002	0.028**	-0.005	-0.005
	(0.009)	(0.013)	(0.011)	(0.010)

Notes:

1. *Standard errors* are in parenthesis.
2. ***, **, *denote level of significance at 1%, 5%, and 10%, respectively.