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R&D AND PRODUCTIVITY IN THE SPANISH´S MANUFACTURING FIRMS

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ABSTRACT

The Spanish R&D to GDP ratio is low compared to other leading economies during the last decade. This paper uses data of a sample of Spanish manufacturing firms over the period 1990-2001 to investigate the relationship between labour productivity and R&D capital at firm level. A Cobb-Douglas function including R&D intensity is estimating using the panel data with instrumental variables method. The results indicate that a positive and significant role for the firm's own R&D capital is only found in firms located in technology intensive sectors. It also appears that some firm's characteristics (firm size and the integration of the firm in a corporate group) play a significant role in influencing private output.

Key words: Productivity, R&D, Size. **JEL:** J23, L11, L60.

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1. INTRODUCTION

The literature on the effects of Research and Development (R&D hereafter) stresses their importance as a key determinant of economic growth. Having recognised this contribution, it is only recently that the empirical measure of the magnitude of such effects has become a major focal point in the research. Most empirical studies estimate the impact of R&D using different approaches (Tsai and Wang, 2003; Hall and Mairesse, 1995) and data at various levels of aggregation, although most concentrate on the firm or industry level[1]. The main evidence consists of econometric estimates of the elasticity of output with respect to R&D, with a wide range of results.[2] Some of the R&D analysis have incorporated relevant information on the firm's characteristics with the aim of obtaining a clearer understanding of the effects (Queiroz *et al*, 2006).

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[1] See comprehensive surveys of the impact of R&D on productivity in Mairesse and Sassenou, 1991, and CBO, 2005.
[2] In Griliches (1998) the central tendency they found for R&D output elasticity runs from about 0.10 to about 0.20.

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In this context, the evidence obtained for Spanish companies, though growing, continues being reduced[3], and, to a greater extent, has been dedicated to analyzing the effects of R&D on employment (García *et al.*, 2002; Calvo, 2006). The analysis of the Spanish case is particularly interesting since it presents some very low rates of R&D investment in percentage of GDP—in 2004 it was 1.07% compared to 1.9% in the EU-15, and 2.26% in the OECD[4]. In fact, such investment rate does not seem the most appropriate for one of the ten richest economies in the world. In this sense, the analysis play carried out in this paper will offer evidence that will be helpful in understanding the situation of R&D in Spain.

The principal aim of this paper is to broaden the existent results, addressing some of the key questions raised in the literature. With this objective, we first estimate R&D elasticity using a Cobb-Douglas production function with a factor representing R&D undertaken by the firm itself[5]. Secondly, we determine how that result responds to changes in underlying assumptions (such as constant returns to scales in the private inputs) with further analysis of the different impact of R&D on high-tech and conventional firms. The paper documents these R&D output elasticity differences on the basis of a micro-panel sample of Spanish manufacturing firms using a dataset for the period 1990-2001 (Survey of Company Strategies, ESEE). Specifically, in this study we pay attention to the role played by the characteristics of the industries in explaining differences in the impact of R&D capital productivity. The firm's level panel structure of the information permits to examine to what extent the following conditions affect a firm's output: the size of the firm, whether it is quoted on the stock exchange, whether it is set up by public capital, whether the company is integrated in a group of companies, and whether it belongs to a technology-intensive sector. Furthermore, in this study we have tried to separate the effects arising from these firms' characteristics.

The remainder of this paper is organized as follows. In the next section we introduce the empirical model and estimation technique. In section 3 we briefly describe the data and examine the results, which are presented for the full sample of firms, and for high-tech and conventional firms, separately. We conclude with some remarks on our findings in the final section, where we also offer some suggestions for further research.

2. MODEL SPECIFICATION AND ESTIMATION TECHNIQUE

Following the literature in using the Cobb Douglas function to analyse the contribution to private output from R&D (see for example, Wakelin, 2001; Añon Higón, 2007), the model used for the analysis is built on the production function approach, where a measure of R&D efforts is included as one of the production factors. Productivity is measured as labour productivity and the assumption of constant returns to scale of private capital and labour is explicitly tested. For estimation purposes, the production function of the *i* manufacturing firm in year *t* is represented by the following Cobb Douglas production function:

[3] In the case of Spain, there also exist some works that have previously estimated the output elasticity of R&D. Beneito (2001) offers a revision of these papers and the R&D elasticities ranges form 0.047 to 0.18.

[4] Source: OECD- "Main Science and Technology Indicators". 2006.

[5] By considering the firm´s own technological resources we can attempt to estimate the direct contribution of R&D efforts to its private output.

$$Y_{it} = A^{\lambda} L^{\alpha}_{it} K^{\beta}_{it} R^{\pi}_{it} e^{\varepsilon it} \tag{1}$$

Where Y_{it} is the measure of output (value added) for firm i at time t, A is a parameter representing all the impact of external effects (to firm knowledge)[6], L_{it} denotes the number of workers employed, K_{it} is a measure of physical capital, and R_{it} is the R&D capital and is a measurement of the stock of R&D. The parameters α, β and π are the elasticities of output with respect to physical capital, labour, and R&D capital. λ represents disembodied technical change, and ε is an error term.

Taking the natural log of Eq. (1), and after assuming constant returns to scale in traditional inputs, one can rearrange the equation to yield:

$$\log(Y_{it} / L_{it}) = \lambda + \beta \log(K_{it} / L_{it}) + \pi_s \log(R_{it}) + (\alpha + \beta - 1) \log(L_{it}) + \sum_{i=1}^{5} \delta_i D_i + \sum_{t=1}^{11} \delta_t D_t + \varepsilon_{it} \tag{2}$$

$$i = 1, ..., 5$$
$$t = 1, ..., 11$$

Dummies variables have been introduced to reflect the characteristics of the firms under study and time dummies in order to control unobserved differences in time. In addition to the observable firm characteristics specified in Eq. (2), we use the panel data model to explore for unobserved heterogeneity among firms. We allow for the existence of individual effects, which are potentially correlated with the right-hand side regressors, so that

$$\varepsilon_{it} = v_{it} + u_i \tag{3}$$

Here, u_i is a firm effect that corresponds to the permanent, unobserved heterogenity across firms, but not within a firm over time, and v_{it} is a “white noise” error term, representing a period-specific shock for firm i, assumed to be independent across firms and over time. Using a “within firm” panel estimator, a fixed-effect technique to eliminate the individual effect is a standard estimation method.

To deal with the endogenous problem of R&D capital, an estimation technique of panel data with instrumental variables is also employed in this study. Using the setting of linear regression models with predetermined rather than exogenous right-hand side variables, panel data with instrumental variables proves to be better because it is robust in the presence of heteroscedasticity across firms and has a correlation disturbance within firms over time. According to the microeconomics of R&D-based endogenous theories, we assume that the predetermined R&D intensity constitutes valid instruments.

[6] Following Rogers (2006), the presence of A in (1) requires some explanation. In economic theory, A represents the level of knowledge or technology of the firm, which would include any contribution from in-house R&D. However, in the empirical R&D productivity literature some authors leave in the A term, although they do not define it (e.g. Hall and Mairesse, 1995), while others omit it entirely (e.g. Bond *et al.*., 2003). Leaving A in (1) makes it clear that there can be external, knowledge- related effects on productivity, perhaps due to spillovers.

In this study, whether or not certain firm characteristics determine the firm's output is investigated. Furthermore, within this study firm characteristics are treated as moderator variables rather than independent. To achieve this goal, we have included in the model two sets of dummies. The first of these is a proxi for time effects D_t, while the second captures company characteristics, i.e., if it belongs to a technology-intensive sector (D_1), if the company has at least 200 wage-earners (D_2), if it is quoted on the stock exchange (D_3), if it is part of a corporate group (D_4), and if it is set up by public capital (D_5).

3. DATA AND RESULTS

The database used in this study is the Survey of Company Strategies (ESEE). The ESEE, an annual representative survey of manufacturing companies, was undertaken in Spain for the Ministry of Industry during the period 1990-2001. A subsample of 125 companies (which fulfilled the condition of full and complete participation for all the years the survey was performed) was then extracted. The definition of the variables used, whether raw or derived, is explained in detail in Appendix[7].

A series of panel data estimations are presented in Tables 1 and 2. The model is estimated for all the sample of firms (Table 1), and with high-tech and conventional firms separated (Table 2). The model with the stock of R&D capital is estimated using fixed effects model (I) and the panel data with instrumental variables method (II). Due to the rearrangement of the productivity relationship in labour productivity, we also check for constant returns to scale.

TABLE 1. COBB-DOUGLAS PRODUCTION FUNCTION DEPENDENT VARIABLE: LN (GVA_{IT} /$LABOUR_{IT}$). TOTAL SAMPLE INCLUDING YEAR DUMMIES

	Fixed effects Model (I)	Instrumental variables (II)
Constant	9.89(23.96)**	9.14(17.50)**
Ln($Labour_{it}$)	-0.55(-15.42)**	-0.49(-11.38)**
Ln(Private $capital_{it}$/$Labour_{it}$)	0.16(6.54)**	0.19(6.56)**
Ln($R\&D_{it}$/$Labour_{it}$)	0.02(1.60)*	0.06(2.55)**
D_1	0.29(4.08)**	0.28(3.60)**
D_2	0.06(0.35)	0.16(0.85)
D_3	0.16(1.78)**	0.12(1.11)
D_4	0.10(1.86)**	0.10(1.62)*
D_5	-0.11(-1.05)	-0.04(-0.35)
F-Test individual effects	F(124,1298)=11.47	F(124,1178)=9.94
Hausman test	$\chi^2(18)=6.81$	$\chi^2(18)=59.06$
F-test of significance	F(19,1298)=33.60	F(143,1178)=30.72
ρ	0.73	0.71
Observations	N=1500	N=1375

ρ: is the percentage of variance displayed by the fixed effects.
t-statistic in paretheses
* Parameter signifcant at 90%.
** Parameter signifcant at 95%.

[7] Details of the design and results of the ESEE can be found in Fariñas and Jaumandreu (1999).

The necessity of controlling the specific effects of each company has been verified applying the contrast F of individual effects, for that the reason the function by means of panel data has been chosen. Next, the Hausman test has allowed us to contrast the existence of a correlation between the regressors and the individual effects, so the model we take into account is that of fixed effects (column I). As it has been mentioned in recent theoretical literature, R&D is predetermined rather than an exogenous variable, implying that the estimate of R&D capital may suffer a bias in the estimation presented in column I. In column II, we use the panel data with instrumental variables approach to the panel data model to investigate the importance of endogenous effects. Assuming that the predetermined R&D capital constitutes valid instruments, we use one-year lagged R&D capital as an instrument. The estimates of the production function include year dummy variables[8].

As Table 1 and 2 show, the F statistic demonstrates that the significance of the estimation is high. The coefficient on the labour variable, which is included to check for constant returns to scale of capital and labour, is significantly different from zero for all firms; when the sample is split, this result is also found for high-tech and conventional firms. Diminishing returns are present in all cases, i.e. the sign on the variable is negative and significant[9]. The estimate of R&D capital elasticity (π) is positive and significant, lying between 0.02 (Model I) and 0.06 (Model II) for all the firms, showing that R&D has a reduced but positive impact on labour productivity. If the results obtained in column II are examined, it is clear that the instrumentation of R&D capital reinforces the positive sign of the coefficient. Likewise, the estimation with instruments increases the significance of the parameter π to 95%. The results indicate that if R&D expenditure increases by 1%, labour productivity will be increased by 0.06 %. Interesting results emerge when we separate firms into two groups according to the intensity in technology. The estimates for the two groups are indeed rather distinct. The estimate of R&D capital elasticity for high-tech companies is positive and significant with a higher value than for the total sample (0.09), but R&D elasticity becomes insignificant for the conventional firms.

In this paper we also focus on how a firm's characteristics affect private output. On this point, it should be noted that the coefficient of the dummy variables shows great stability in its sign and significance in all the estimations. The variables size and the degree of the technological intensity of the companies have a positive effect on the labour productivity in all the firms. When the sample is split into the two categories studied, the incorporation in a group of companies has a positive effect on productivity in the two groups. In the case of conventional firms, the characteristic of public ownership of companies also plays a significant role.

4. CONCLUSIONS

This paper aims to provide evidence to add to the current knowledge on the effect of R&D capital based on panel data of Spanish manufacturing firms for the period 1990-2001. The empirical exercise performed reflects that, for the whole sample, R&D effort has a significantly positive impact on the firm's labour productivity with a R&D output elasticity of 0.06.

[8] We have also performed the estimation using a linear trend. The comparison clearly showed that using year dummy variables instead of a linear trend makes little difference in the estimates of the whole sample and the subsamples.
[9] This type of result is frequent in the literature (see Wakelin, 2001, Griliches and Mairesse, 1991).

TABLE 2. COBB-DOUGLAS PRODUCTION FUNCTION DEPENDENT VARIABLE: LN(GVA_{IT} /$LABOUR_{IT}$). INCLUDING YEAR DUMMIES

	Fixed effects Model (I)	**Instrumental variables (II)**
Conventional firms sample		
Constant	11.21(17.23)**	10.76(13.19)**
Ln($Labour_{it}$)	-0.51(-6.00)**	-0.47(-4.79)**
Ln(Private $capital_{it}$/$Labour_{it}$)	0.09(2.20)**	0.14(2.66)**
Ln($R\&D_{it}$/$Labour_{it}$)	0.01(0.38)	0.02(0.57)
D_1	-0.13(-0.96)	-0.14(-0.94)
D_2	-	-
D_3	0.01(0.03)	-0.10(-0.55)
D_4	0.14(1.28)*	0.19(1.56)*
D_5	0.19(1.24)	0.29(1.71)**
F-Test individual effects	F(22,232)=22.42	F(22,211)=20.41
Hausman test	$\chi^2(17)=25.12$	$\chi^2(17)=26.48$
F-test of significance	F(18,232)=5.62	F(40,211)=5.55
ρ	0.88	0.87
High-tech firms sample		
Constant	9.91(23.37)**	8.63(13.92)**
Ln($Labour_{it}$)	-0.54(-13.16)**	-0.46(-9.36)**
Ln(Private $capital_{it}$/$Labour_{it}$)	0.18(6.11)**	0.21(6.12)**
Ln($R\&D_{it}$/$Labour_{it}$)	0.03(1.69)**	0.08(2.91)**
D_1	0.39(4.65)**	0.37(4.23)**
D_2	-	-
D_3	0.17(1.57)*	0.15(1.16)
D_4	0.12(1.85)**	0.11(1.44)*
D_5	-0.21(-1.61)*	-0.19(-1.15)
F-Test individual effects	F(100,1039)=8.98	F(100,942)=7.74
Hausman test	$\chi^2(18)=62.67$	$\chi^2(18)=23.37$
F-test of significance	F(18,1039)=30.59	F(118,942)=28.01
ρ	0.65	0.61

ρ: is the percentage of variance displayed by the fixed effects.
t-statistic in paretheses
* Parameter signifcant at 90%.
** Parameter signifcant at 95%.

We also find that the firm's characteristics of size and the belonging to a technology-intensive sector exert a positive effect on this relationship. When the sample is divided, the impact of R&D on a firm's output is significantly different for high-tech and conventional firms: the R&D elasticity for high-tech firms increased to 0.08, but it is not significant for conventional firms. In this case, the characteristic of incorporation in a corporate group is the most relevant in order to determine the private output of the firms in the two subsamples. Another point worth noting is that the estimates of the impact of R&D on private output might induce an upward bias if the endogeneity problem of R&D is not controlled.

The evidence from this study shows that the relationship between R&D and firm output is relevant for Spanish manufacturing firms, supporting the notion that R&D policies that stimulate these firms to enhance efforts in R&D enables them to have superior performance in terms of labour productivity. Therefore, these results justify the public policies directed at the promotion of R&D that have been undertaken in Spain in the past decades.

Appendix
Construction of the variables

Gross Value Added (Y)

The Gross Value Added (in 1990 pesetas) has been calculated as the monetary value of production (sales plus variation of stocks) minus the intermediate consumption divided by a deflator of production d_{it}^{Y}. This deflator has been constructed for each company, based on the available information concerning the variation in annual sales prices π_{it}^{S}. The annual expense on intermediate input is constructed as the sum of the energy and fuel purchases, raw materials, and payments for external services.

Technological capital stock (R)

Technological capital stock, R_{it}, is defined as the accumulation (net of depreciation) of annual expenditure on R&D. The stock of technological capital has been constructed for each company by means of the permanent inventory method referred to in equation (4). As in the majority of existing studies for the case of Spain (see Marra, 2004), in this paper a constant rate of depreciation of 15% is used. In order to calculate the stock of technological capital for the first year of the sample, we have used the procedure proposed by Beneito (2001):

$$R_1 = I_1(1+m)\left[\left(1-\eta^T\right)/(1-\eta)\right] \qquad [4]$$

$$\eta = (1-m)(1-\delta) \qquad [5]$$

where I1 is the investment in year 1, m is the average growth rate of companies which undertake R&D, t is the number of years since the founding of the company, and δ is the (constant) rate of depreciation of R&D stock.

Stock of productive assets (K)

The stock of productive assets, K_{it}, is defined as the accumulation (net depreciation) of the annual investment in machinery, buildings, transportation elements, and the rest of the assets in pesetas (constants) from 1990. The stock of technological capital has been constructed for each company following the perpetual inventory method.

Number of workers (L)

The variable L represents the annual number of full-time workers in each company. For that, the number of workers that work during the whole year and those who work with contracts of less than one year duration has been taken into account. Furthermore, the full or part-time schedule of the workers has been taken into consideration.

Dummy variables

All the estimations include dummies which try to approximate the time trend present in the production function. There are also five firm dummies to account for the following company characteristics:

D1: Size

If the company has at least 200 wage-earners ………….. '1'.

If the company has less than 200 wage-earners …………. '0'.

D2: Sector of activity

If the company belongs to sectors 9, 14, 15, 16 and 17 ………….. '1'.

(technology intensive)

If the company does not belong to these sectors ……………..... '0'.

D3: Stock market standing

If the company is quoted on the stock market ………….. '1'.

If the company is not quoted ………….. '0'.

D4: Incorporation in a corporate group.

If the firm is in a company group …………… '1'.

If the company is not incorporated …………… '0'.

D5: Public participation

If the company is constituted by public capital …………… '1'.

If the company is not constituted by public capital …………. '0'.

5. REFERENCES

Añón Higón D. (2007): "The impact of R&D spillovers on UK manufacturing TFP: A dynamic panel approach", *Research Policy*, 36, 7, pp. 964-979.

Beneito P. (2001): "R&D productivity and spillovers at a company level: evidence from Spanish panel data", *Investigaciones Económicas*, 25, pp. 289-313.

Bond S., Harhoff D. and van Reenen J. (2003): "Corporate R&D and productivity in Germany and the UK", CEP Discussion Paper Centre for Economic Performance LSE, CEPDP0599.

Calvo J.L. (2006): "Testing Gibrat´s law for small young and innovating firms", *Small Business Economics,* 26, pp. 117-123.

Comin D. (2004): "R&D: a small contribution to productivity growth", NBER working paper 10625.

Congressional Budget Office (2005): "R&D and productivity growth", Background papeer, Congress of the United States.

Fariñas J.C. and Jaumandreu J. (1999), "Diez años de Encuesta sobre Estrategias Empresariales", *Economía Industrial*, 329, pp. 29-42.

García A., Rodríguez C. and Jaumendreu J. (2002), "Innovación y empleo: evidencia y escala de empresa", *Economía Industrial*, 348, pp. 111-118.

Mairesse J. and Griliches Z. (1991): "**Heterogeneity in Panel Data: Are There Stable Production Functions?**" NBER Working Papers 2619, National Bureau of Economic Research.

Griliches Z. (1998): *R&D and productivity: the econometric evidence*, Chicago: University of Chicago Press.

Hall B.H. and Mairesse Z. (1995): "Exploring the relationship between R&D and productivity in French manufacturing firms", *Journal of Econometrics*, 65, pp. 263-293.

Marra M.A. (2004): " Incentivos fiscales, inversión en actividades de I+D y estructura de costes. Un análisis por tamaño para una muestra de empresas manufactureras españolas, 1991-1999", *Hacienda Pública Española / Revista de Economía Pública*, 170, pp. 9-37.

Mairesse J. and Sassenou M. (1991): *"R&D and productivity: a survey of econometric studies at the firm level", OECD Science-Tecnology Review*, 8, pp. 9-44.

OECD (2006): "Main Science and Technology Indicators", Paris.

Queiroz V., Pindado J. and de la Torre C. (2006): *How do firm characteristics influence the relationship between R&D and firm value*, Working Papers 09/06 "New Trends on Business Administration", Universities of Valladolid, Burgos and Salamanca.

Rogers M. (2006): *R&D and productivity in the UK: evidence from firm-level data in the 1990s*, Economics Series Working Papers nº 255, University of Oxford.

Tsai H.K. and Wang J.C. (2005): "Does R&D performance decline with firm size?- A re-examination in terms of elasticity", *Research Policy*, 34, pp. 966-976.

Tsai H.K. and Wang J.C. (2003): "*Productivity growth and R&D expenditure in Taiwan´s manufacturing firms*", *Research Policy*, 34, pp. 966-976.

Wakelin K. (2001): "Productivity growth and R&D expenditure in UK manufacturing firms", *Research Policy*, 30, pp. 1079-1090.

Yang C.H. and Huang C.H. (2005): "R&D, size and firm growth in Taiwan´s electronics industry", *Small Business Economics*, 25, pp. 477-487.