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"Productivity and innovation spillovers: Micro evidence from Spain"

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Abstract

This article analyses the impact that innovation expenditure and intrasectoral and intersectoral externalities have on productivity in Spanish firms. While there is an extensive literature analysing the relationship between innovation and productivity, in this particular area there are far fewer studies that examine the importance of sectoral externalities, especially with the focus on Spain. One novelty of the study, which covers the industrial and service sectors, is that we also consider jointly the technology level of the sector in which the firm operates and the firm size. The database used is the Technological Innovation Panel (PITEC), which includes 12,813 firms for the year 2008 and has been little used in this type of study. The estimation method used is Iteratively Reweighted Least Squares method (IRLS), which is very useful for obtaining robust estimations in the presence of outliers. The results confirm that innovation has a positive effect on productivity, especially in high-tech and large firms. The impact of externalities is more heterogeneous because, while intrasectoral externalities have a positive and significant effect, especially in low-tech firms independently of size, intersectoral externalities have a more ambiguous effect, being clearly significant for advanced industries in which size has a positive effect.

JEL classification: D24, O33
***Keywords*:** Productivity, innovation, sectoral externalities, firm size

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1. Introduction

Ever since the work of Griliches (1979, 1986), the relationship between innovation and productivity has been widely studied by many authors on both national and sectoral as well as firm levels. The Cobb-Douglas production function is normally used for the empirical analysis, extending the traditional inputs of physical capital and labour to include innovation expenditures. The results obtained depend on the geographical area analysed, the database and the methodology used. The evidence certainly points to a positive and significant relationship between innovation and productivity on a firm level (see Mairesse and Sassenou, 1991, for a detailed study, and also – to name but a few – Hall and Mairesse, 1995, for France; Harhoff, 1998, for Germany; Lotti and Santarelli, 2001, for a comparative study of Germany and Italy; and Parisi *et al*., 2006, for Italy).

Other papers use a structural model based on the Crépon, Duguet and Mairesse approach (1998), known in the literature as the *CDM model*, which also finds a positive impact of innovation output on productivity. This type of paper includes those by Janz *et al*. (2004) for Germany and Sweden; Griffith *et al*. (2006), who carry out a comparative study of France, Germany, Spain and the United Kingdom; and Hall *et al*. (2009) for Italy.

However, the impact of innovation on productivity varies depending on a number of factors, including the economic sector. On this aspect most articles agree that the impact that R&D expenditures has on productivity is greater in high-tech sectors than in low-tech sectors (see Verspagen, 1995, for 9 OECD countries; Tsai and Wang, 2004, for Taiwan; Ortega-Argilés *et al*., 2010 and 2011, for European firms).

Another factor that may have an influence on productivity is firm size, although as far as this aspect is concerned there is no consensus regarding the magnitude of this effect. Thus while some authors, using a structural model, obtain an inverse relationship between size and productivity (see Huergo and Moreno, 2004, and Hall *et al.,* 2009), others find the opposite to be true (Griffith *et al*., 2006). Another interesting aspect that has hardly been analysed in the literature is whether size influences the returns firms obtain from innovation, bearing in mind that the larger the firm, the more innovation it carries out (see Huergo and Jaumandreu, 2004). According to Castany *et al*. (2009), the size of Spanish firms has an influence on the returns obtained from investment in both innovation and human capital, with the largest firms being the ones that benefit most from these investments.

The benefits deriving from innovation in a firm (or sector) spill over towards others due to the firm's inability to seize all the benefits deriving from its investment. Therefore, when the impact of innovation on productivity is examined, these externalities need to be taken into account. In this respect there seems to be no general consensus as to the effect these externalities have on productivity. Although there are numerous studies that find a positive relationship (see Griliches, 1992, and Nadiri, 1993), other more recent papers arrive at different conclusions (see for example Klette, 1994, for Norway; Los and Verspagen, 2000, for American firms; Harhoff, 2000, for Germany; and Wakelin, 2001, for the United Kingdom among others). It should be borne in mind that the results depend a great deal on what variable is used to quantify the externality (R&D expenditures, information on patents, surveys on innovation, etc.), as well as on what sector or country is being analysed and what transmission mechanism, i.e. "technology flow matrix", is used to weight the relationships between sectors[1].

If we focus on the case of Spain, the relationship between innovation and productivity has been dealt with by a number of authors, also finding innovation to have a positive impact on productivity. However, one limitation that generally can be found in most studies is that the analysis is restricted to manufacturing firms based on the use of the *Encuesta sobre Estrategias Empresariales (ESEE)*[2]. Among the most up-to-date papers that use this database are those by Vivero (2002), Huergo and Moreno (2004), Huergo and Jaumandreu (2004), Maté-García and Rodríguez-Fernández (2002, 2008), Rodríguez-Fernández and Maté-García (2006), Rochina-Barrachina *et al*. (2010) and Casiman *et al*. (2010), to name but a few. Therefore there are very few papers that carry out a joint analysis of the industrial and service sectors, although some notable studies are those by Jaumandreu (2009), who uses the PITEC database for Spain, and Segarra-Blasco (2010) and Segarra-Blasco and Teruel (2011), who use data from the CIS4 for Catalonia.

[1] Various alternatives can be used to define this flow matrix, such as that based on patents or that relating to commercial relations using the input-output table.
[2] The ESEE is a firm-level survey of Spanish manufacturing which has been collecting annual information since 1990.

The literature on the effect of spillovers on productivity in Spain is even smaller. Some articles, such as those by López-Pueyo and Sanaú (1999) and Gumbau-Albert and Maudos (2006), find that externalities are positive and significant in explaining productivity. However, other authors obtain different results depending on the firm's economic sector or technology level, and no consensus exists in this area. Thus Beneito (2001) analyses the impact of externalities on productivity in Spanish firms distinguishing according to technology level, while Segarra-Blasco (2007) analyses the impact of intrasectoral and intersectoral externalities in Catalan firms.

The aim of this paper is to analyse to what extent technology level and firm size affect the return that firms obtain from their investment in innovation. Also, and bearing in mind the small amount of literature on the subject in Spain, it aims to analyse to what extent the above factors influence the benefit that firms obtain from innovations carried out by others (either all the other firms in the same sector or all other sectors). This will be carried out by taking into consideration a sample of 12,813 Spanish firms belonging to both the industrial and service sectors. Thus the article will make a thorough analysis of the relationship between innovation and productivity, contributing as added value different aspects such as considering the indirect effect of size on productivity through innovation. It should be pointed out that the analysis of externalities is carried out taking into account technology level and firm size, both separately and jointly. It should also be mentioned that the study breaks new ground in that it focuses on both the industrial and service sectors, thereby aiming to overcome a severe limitation given that, as we have already seen, most studies in this area focus only on the manufacturing sector.

The structure of the paper is as follows. After this introduction, Section II presents the economic model, Section III describes the database and empirical model, Section IV presents the results obtained, and finally the conclusions are set out in Section V.

2. Economic model

The model adopted to estimate the relationship between innovation and productivity is the extended Cobb-Douglas production function, which apart from including conventional production factors (physical capital and labour) also incorporates human capital and innovation. Assuming constant returns to scale:

$$y_{i,s} = A_{i,s} \cdot k_{i,s}^{\alpha} \cdot h_{i,s}^{\beta} \cdot i_{i,s}^{\gamma} \qquad [1]$$

Thus the labour productivity of firm *i* belonging to sector *s* $(y_{i,s})$ is a function of physical capital per employee $(k_{i,s})$, of human capital $(h_{i,s})$, of innovation per employee $(i_{i,s})$ and of the firm's technology level $(A_{i,s})$, with α, β, γ being the returns on physical capital, human capital and innovation respectively.

Human capital (h)[3] has been included in the Equation [1] because as the workers become better trained and acquire more skills they can carry out tasks more efficiently. The literature shows how human capital has a significant influence on firm productivity[4] in such a way that the more qualified workers the firm has, the more productive it will be. In the same way, innovation (i) has been included as a production function input and a variable of interest in our study. As mentioned in Section I, this is a very important factor for increasing firm productivity.

With respect to the technology level $A_{i,s}$ in Equation [1], it will be assumed in this paper that an external effect exists due to the public nature of knowledge[5]. Hence one firm's technology depends on the innovation made by all the other firms:

$$A_{i,s} = A \cdot \left(S^{INTRA}\right)^{\delta_1} \cdot \left(S^{INTER}\right)^{\delta_2} \qquad [2]$$

where A is a constant to denote a common technology level for all the firms; $S_{i,s}^{INTRA}$ is the intrasectoral externality of firm *i* in sector *s* and includes the innovating effort made by all the other firms in the same sector; and $S_{i,s}^{INTER}$ is the intersectoral externality understood as the innovation made by the firms in all the other sectors.

[3] It must be pointed out that there are few microeconomic studies that incorporate human capital and innovation as factors in the production function, especially in the case of Spain.
[4] See for example Black and Lynch (1996) and Haltiwanger *et al*. (1999) for the United States, Turcotte and Rennison (2004) for Canada, Arvanitis and Loukis (2009) for Greece and Switzerland, Yang, Lin, Ma (2010) for China, and Lee (2011) for Malaysia.
[5] This public nature is due to the fact that knowledge is non-rival (its use by one firm does not prevent others from using it at the same time) and non-excludable (no firm can be excluded from using it).

As regards externalities, it has to be taken into account that knowledge transfer between firms can come about in different ways: learning what other firms do either via the movements of workers themselves or through reading articles in journals, attending conferences, disclosure of a patent, etc. The result is that one firm uses the knowledge generated in another firm without paying for it directly.

Thus by combining Equations [1] and [2] we see that a firm's labour productivity is explained through its own investments (in physical capital, human capital and innovation) as well as through the innovation effort made by all the other firms, captured as an externality:

$$y_{i,s} = A \cdot k_{i,s}^{\alpha} \cdot h_{i,s}^{\beta} \cdot i_{i,s}^{\gamma} \cdot \left(S_{i,s}^{INTRA}\right)^{\delta 1} \cdot \left(S_{i,s}^{INTER}\right)^{\delta 2} \qquad [3]$$

From Equation [3] it can be concluded that (under the assumption that $\delta_1 \neq 0$ and $\delta_2 \neq 0$), even though a firm makes no investment in innovation, it could still benefit from the innovation carried out by all the other firms and thereby increase its own productivity.

3. Data and empirical model

The database used is the Technology Innovation Panel (PITEC), which provides information on the technological innovation activities of Spanish firms for the period 2003-2008[6]. The National Institute of Statistics (INE), in consultation with a research group and under the sponsorship of the Spanish Foundation for Science and Technology (FECYT) and the Foundation for Technological Innovation (COTEC), is responsible for building up this database. PITEC is built upon the Spanish Innovation Survey carried out by the INE, which in turn is based on the Community Innovation Survey (CIS) which follows guidelines laid down by the OECD's Oslo Manual and, through the use of a standardized questionnaire, enables comparisons to be made between countries.

PITEC is a data panel based on a representative selection of firms, which makes it possible to carry out repeated observations of the economic units included over time

[6] The information for 2009 was published after this paper was written.

and thereby develop much more precise estimations of the evolution of R+D+I activities in the business sector (innovation expenditures, composition of the samples, etc.), determine the impact of innovation (different effects on productivity) and identify the various strategies in the decisions adopted by firms when introducing innovations into their business (for instance the different compositions of internal and external R&D expenditures as a part of total expenditures). The panel is made up of four non-excludable samples: (i) firms with 200 or more employees, (ii) firms with internal R&D expenditures, (iii) firms with fewer than 200 employees with external R&D expenditures but which carry out no internal R&D, and (iv) firms with fewer than 200 employees with no innovation expenditures.

The number of firms included in the sample for 2008 is 12,813. After a filtering process[7], only those firms belonging to the industrial and service sectors were selected, thereby excluding the primary sector and construction, and at the same time only those firms with 10 or more employees have been taken into account[8]. In the end the sample to be worked with consisted of 9,197 observations.

PITEC provides information on innovation activities, such as types of innovation, cooperation between firms and number of patents, along with information on individual firm characteristics such as sales, volume of exports, workers and their level of education, the market in which the firm operates, sources of finance, etc.

There is a double advantage to using this database for Spain. Firstly it provides information on both the industrial and service sectors, which means that one serious limitation can be overcome given that most studies in this area focus only on the manufacturing sector, generally using the *ESEE*. And secondly, it contains a high level of sectoral information broken down into details covering 52 industrial and service sectors (see Table 3 in the appendix). This enables a much richer study to be made of the different behaviours between sectors with different technology levels and, in turn, makes a more interesting study of intersectoral externalities possible.

[7] This filtering process consisted of eliminating those observations that include some incident (due to problems of confidentiality or takeovers, mergers, etc) and those with any anomaly (such as a nil sales).
[8] The population area taken into account is that defined in the Spanish Innovation Survey on which PITEC is based.

Based on the expression of the theoretical model in Section II, and with the information supplied by the PITEC database, the following econometric model has been specified:

$$y_{i,s} = \alpha + \beta k_{i,s} + \lambda h_{i,s} + \gamma i_{i,s} + \delta_1 S_{i,s}^{INTRA} + \delta_2 S_{i,s}^{INTER} + \varepsilon_{i,s} \qquad [4]$$

where $y_{i,s}$ approximates the quotient of sales per employee, $k_{i,s}$ is the ratio between investment in material goods and number of employees, $h_{i,s}$ is the percentage of employees with higher education, and $i_{i,s}$ is defined as total innovation expenditure[9] per employee carried out by firm *i* in sector *s* [10].

As regards externalities, due to the great many different ways in which spillovers can appear, measuring them is a complicated task. In our case the innovation expenditure will be used to approximate them. Thus to begin with, the intrasectoral externalities corresponding to firm *i* belonging to sector *s* are defined as:

$$S_{i,s}^{INTRA} = \sum_{j \neq i} I_{js}$$

or in other words the total innovation expenditure made by all the other firms in the same sector. With this definition we capture the technological effort of the sector in which the firm is located. However, clearly not all the innovation expenditure made by all the other firms will benefit firm *i*, but it will serve as an indicator of the magnitude of technological knowledge current in the sector.

Secondly, the intersectoral externalities corresponding to firm *i* belonging to sector *s* are defined in the following way:

$$S_{i,s}^{INTER} = \sum_{m \neq s} w_{sm} \cdot I_{jm}$$

[9] Here it should be pointed out that a firm is said to carry out innovation when it introduces products (goods or services) and/or processes that are new or a significant improvement on the previous ones. It is normal to approximate this variable through R&D expenditures, but it needs to be taken into account that this is only part of technological innovation as a whole. Therefore, in order to approximate innovation variable (*i*) we will use total innovation expenditures, which includes internal, external R&D, acquisition of machinery, equipment and hardware/software, acquisition of other external knowledge, training of staff directly involved in developing the innovation, introduction of innovations into the market, and design and other preparations for production and distribution.

[10] Logarithms have been taken of variables y, k, i. In any case where the observation is zero, it will be replaced by ln(10^{-7}). No logarithms are applied in the case of variable h as it is a percentage.

or in other words the weighted sum of all innovation expenditures carried out by the firms in all the other sectors. Weighting w_{sm} is defined as the quotient between the intermediate purchase by sector *s* of goods and services supplied by sector *m* and the total sum of intermediate purchase of sector *s*. Thus the influence that innovation expenditure made by firms in sector *m* has on the productivity of firm *i* in sector *s* is based on the relative importance that said sector *m* has as supplier to sector *s*. To construct the w_{sm} weights we have used the symmetric input-output table for Spain for 2005 (the latest year available), and for this an exercise of correspondence has had to be carried out between the branches of business activity by which the PITEC data are classified and the branches of business activity in the input-output table.

In line with the aim of this paper and for the purposes of analysing whether the effects of the returns from innovation and externalities on productivity vary depending on the sector's technology and firm size, the total sample of 9,197 firms has been divided up according to:

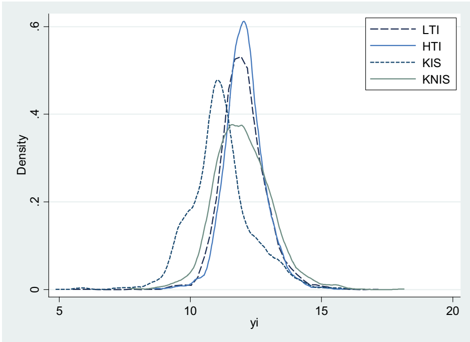
(i) The technology level of the sector in which the firm operates. For this we have used the classification compiled by the OECD (2001) and grouped the firms by sector into the following categories:
  - Low and medium-low tech industries (LTI)
  - Medium-high and high tech industries (HTI)
  - Knowledge-intensive services (KIS)
  - Knowledge no intensive services (KNIS)

(ii) The size of the firm, distinguishing between:
  - Small firms: from 10 to 49 employees.
  - Medium-sized firms: from 50 to 199 employees.
  - Large firms: 200 or more employees.

To see the distribution of firms according to sub-samples, as well as a descriptive analysis of the main variables of interest, see Table 4 in the appendix.

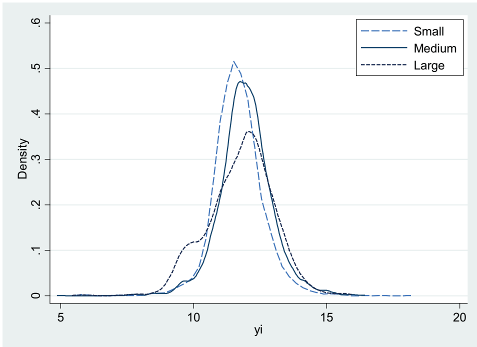
Before showing the results of the estimations of the empirical model for the sub-samples above, and with the intention of corroborating the need to study the firms belonging to these sub-samples separately, we present the density functions of the logarithm for labour productivity according to technology level and firm size.

Figure 1. Distribution of productivity according to technology level



Source: Own based on the PITEC database

Figure 2. Distribution of productivity according to firm size



Source: Own based on the PITEC database

In Figure 1 it can be seen how the density functions for industries are more leptokurtic than those corresponding to the service sector, which are more dispersed. Although it is true that the functions for the industrial sector are very similar, it seems that high-tech industries (HTI) present a probability concentration with a slightly higher average than those low-tech (LTI). Thus the more advanced industries are situated a little further to the right on the graph where productivity is higher. Knowledge no intensive services (KNIS) show greater dispersion and, on average, slightly lower productivity than industry. Finally, knowledge-intensive services (KIS) are those situated furthest to the left on the graph, thereby obtaining the lowest productivity levels. They also present a high probability concentration in the left-hand tail, making it clear that within the sector typology there is a group of firms with productivity levels notably lower than the rest[11].

[11] Generally these firms belong to a very heterogeneous branch of business activities known as “Other business activities”, which includes legal and accounting activities, advertising, personnel selection and placement, investigation and security services, industrial cleaning activities, etc.

As regards Figure 2, it can be seen that there are differences depending on the firm size. Thus the density functions move further right as the size increases. Therefore the small firms present a density function further to the left on the graph, which indicates lower productivity levels, followed by the medium-sized firms, which are clustered a little further to the right on the graph. Finally, the large firms are those that on average present higher productivity, although greater dispersion too. In addition, there is a cluster of firms in the left-hand tail which, despite their size, have productivity levels notably lower than the rest[12].

These graphs therefore show that, without taking other factors into account, labour productivity is distributed differently depending on the economic sector's technology level or firm size. In particular, industries present higher averages than services and also less dispersion. Firm size, meanwhile, has a positive influence on productivity because the density function moves rightwards towards greater size, therefore reaching higher productivity levels.

4. Results

Next we will carry out an estimation of Equation [4] using iteratively reweighted least squares (IRLS). This method provides robust estimations in the presence of outliers and non-normality, assigning to each observation a weight inversely proportional to the error committed, i.e. giving more weight to those observations that behave better.

The model is estimated using information for 2008. Here it should be mentioned that a problem that arises when this type of equation is estimated is the temporal relationship between productivity and innovation. Assuming a contemporary relationship between both variables seems inappropriate due to problems of endogeneity, and therefore the innovation expenditure has been lagged one year[13].

[12] This refers to the same firms as footnote 11.
[13] Nevertheless, some authors (Mairesse and Sassenou, 1991, Hall and Mairesse, 1995) find that firm R&D expenditures remain fairly stable over time, and therefore the introduction of a lag has only a small impact on the estimations.

Table 1 shows the results of the estimation for the sample as a whole and also for the sub-samples according to firm size and technology level of the sector in which the firm operates, with the aim of finding out whether there are differences in the returns firms obtain from their own innovation and from externalities.

Firstly it can be seen that when the sample as a whole is used (column 1) the investment in material goods (k_i) has a positive impact on productivity. If a distinction is made according to firm size (columns 2 to 4), the results are seen to be greater for large firms, followed by medium-sized and small firms. When broken down by technology level (columns 5 to 8), it can be seen that investment in physical capital has a greater impact on firms belonging to knowledge-intensive services, followed by high-tech industries and finally low-tech industries. For the knowledge no intensive services (column 7), however, investment in material goods does not give rise to increases in productivity.

In the case of returns on innovation (i_i), the results are similar. In the sample as a whole (column 1), the impact of innovation expenditures on productivity is positive, and when estimating by size sub-samples (columns 2 to 4) it appears to have a positive influence on the returns firms obtain from their investments, since the greater the size of a firm, the more benefits it obtains from its innovation expenditure. Finally, in the breakdown by technology level (columns 5 to 8), it can be seen that it is the knowledge-intensive services that obtain a greater return from innovation expenditures, followed by high-tech industries, knowledge no intensive services and finally low-tech industries. Thus innovation expenditure has a positive and significant influence on productivity in all the firms and it has the greatest influence in those firms that operate in high-tech sectors (both industrial and services). This result coincides with previous studies carried out for OECD countries, Taiwan and Europe (see Verspagen, 1995; Tsai and Wang, 2004; Ortega-Argilés *et al*., 2010 and 2011), in which it is shown that high-tech sectors obtain better returns from innovation than those with lower technology levels.

Table 1. An IRLS estimation for production function: all firms, by size and by technological level. Estimation results of empirical model [equation 4].

Dependent variable: labour productivity	Total (1)	Small (2)	Medium (3)	Large (4)	LTI (5)	HTI (6)	KNIS (7)	KIS (8)
k_i	0.0090*** (0.0009)	0.0067*** (0.0011)	0.0100*** (0.0016)	0.0141*** (0.0019)	0.0072*** (0.0012)	0.0082*** (0.0014)	-0.0008 (0.0022)	0.0128*** (0.0019)
i_i [(a)]	0.0124*** (0.0009)	0.0052*** (0.0011)	0.0101*** (0.0016)	0.0208*** (0.0017)	0.0046*** (0.0011)	0.0060*** (0.0015)	0.0049** (0.0024)	0.0126*** (0.0019)
h_i	-0.0006 (0.0004)	-0.0024*** (0.0005)	-0.0024*** (0.0008)	0.0047*** (0.0009)	0.0053*** (0.0010)	0.0016** (0.0007)	0.0053*** (0.0013)	0.0030*** (0.0007)
$S_{i,s}^{INTRA}$	0.0001*** (0.0000)	-0.0001*** (0.0000)	-0.0001 (0.0001)	0.0003*** (0.0001)	0.0008*** (0.0001)	0.0001*** (0.0000)	0.0045*** (0.0003)	0.0001** (0.0000)
$S_{i,s}^{INTER}$	-0.0020*** (0.0001)	-0.0013*** (0.0001)	-0.0016*** (0.0001)	-0.0032*** (0.0002)	0.0001 (0.0001)	0.0019*** (0.0003)	0.0015*** (0.0002)	-0.0009*** (0.0001)
Constant	12.3338*** (0.0317)	12.1804*** (0.0376)	12.3731*** (0.0550)	12.3737*** (0.0765)	11.4789*** (0.0531)	11.0557*** (0.0968)	10.5900*** (0.1312)	11.3257*** (0.0922)
Size dummy	yes	no	no	no	yes	yes	yes	yes
Wald test for size	47.23***				20.23***	19.07***	4.63***	17.31***
Observations	9,134	3,858	2,534	2,742	3,039	2,262	1,210	2,623
R^2 adjusted	0.2115	0.1207	0.1788	0.3763	0.2006	0.1937	0.3035	0.1870

Note: Low and medium-low tech industries (LTI), medium-high and high tech industries (HTI), knowledge no intensive services (KNIS), knowledge-intensive services (KIS).
A group dummy (which takes the value 1 if the firm belongs to a group of companies) is included in all estimations. Standard errors in parenthesis.
(a) Innovation expenditure per employee is lagged one period.
*** Significant at 1%, ** significant at 5%, * significant at 10%.

If we compare the returns from physical capital and innovation, we can see that the return on physical capital is greater in small firms while the opposite is true in large firms, in which the return on innovation is clearly greater. Also, in all sectors apart from the sample of knowledge no intensive services, the return on physical capital is greater than that from innovation.

As far as human capital (h_i) is concerned, and unlike the positive impact shown in the previous literature, there appears to be no clear result as to its effect on productivity. Thus while on an overall level it is not significant, when it is estimated by size sub-sample a negative coefficient is obtained for small and medium-sized firms and a positive coefficient for large firms. When the data are broken down according to the technology level of the sector in which the firm operates, it can be seen that human capital has a clearly positive and significant impact on productivity, with firms with the least advanced technology levels –low and medium-low tech industries (column 5) and knowledge no intensive services (column 7)– being the ones that obtain the most benefit from employing qualified workers.

The intrasectoral externalities, although small, are positive and significant on an overall level (column 1). In the breakdown by firm size there appears to be no clear conclusion. Thus while large firms (column 4) benefit from the innovation expenditure carried out by all the other firms in the same sector, for medium-sized firms (column 3) the intrasectoral externalities are not significant, and small firms (column 2) show a negative sign for this variable. This result would indicate that this type of firm reduce their productivity by the fact that all the other firms in its sector innovate, which may reflect a possible competition effect. The breakdown by technology level, however, makes it possible to see that intrasectoral externalities have a positive effect on productivity independently of this, thus showing the complementarity of technological effort between firms in the same sector. The more advanced firms obtain less benefit from the innovation expenditure done by all the other firms in their sector (columns 6 to 8) than those firms that form part of less technologically advanced sectors (columns 5 and 7), since they present much greater coefficients. This result is in line with that found by Segarra-Blasco (2007), where it was precisely low-tech industries who benefit more from intrasectoral externalities than firms high-tech firms. This might lead us to believe that there is a “technology threshold” beyond which firms benefit less from the innovation expenditure made by all the other firms in the sector. As regards this aspect, we should draw attention to the capacity of knowledge no intensive services to benefit from these intrasectoral externalities since, as can be seen from the table, they present much higher coefficients than all the other technology levels. To be specific, a firm in knowledge no intensive services would see its productivity increase by 0.45% if the rest of the firms in its sector increased their innovation expenditures by one million euros. However, this change would only be 0.01% if the firm belonged to knowledge-intensive services or a medium-high or high tech industry, and only 0.08% if it were a low or medium-low tech industry.

With regard to intersectoral externalities, in the overall sample they are seen to present a negative sign (column 1). It must be said that this is an unexpected result and counter-intuitive because it would be logical to believe that if all the other sectors innovate, then either the firm should benefit due to some kind of sectoral complementarity or not benefit at all, but in no case does it appear plausible that the firm would be harmed by this innovation. The same conclusion is repeated when carrying out the analysis according to firm size (columns 2 to 4) because, independently of size, the externality presents a negative sign (especially for large firms). However, if the sample is broken down according to technology level (columns 5 to 8), it can be seen that these externalities are not significant for those firms belonging to low-tech industries, while their effect is positive and significant in the case of high-tech industries. This result is consistent with the "absorption capacity" hypothesis put forward by Cohen and Levinthal (1989), which suggests that the degree to which firms benefit from external innovation is strongly dependent on its own innovation expenditure, with firms with greater technological capital being those that obtain the most benefit from externalities. Also, it can be seen that the magnitude of the intersectoral externality is greater than the intrasectorial externality, indicating that productivity in high-tech firms increases more through the innovation carried out by all the other sectors than through the innovation carried out by all the other firms in the same sector. However, intersectoral externalities show a negative effect on productivity in firms belonging to knowledge-intensive services. Finally, in the case of firms belonging to the sample of knowledge no intensive services, intersectoral externalities present a positive and significant coefficient, i.e. these firms undergo increases in productivity due to the innovation expenditure carried out by firms in all the other sectors. This result could reflect a complementarity of technology effort between the different sectors relative to knowledge no intensive services. It should be remembered that, as can be seen in Table 4 in the appendix, knowledge no intensive services show the lowest innovation ratios per employee, which would explain why they benefit more from investments made by all the other firms (both in their own sector and all the other sectors).

At this point in the proceedings it appears that a number of inconsistencies can be observed, such as the negative effect of human capital on small and medium-sized firms when this impact is positive when the data are broken down by the technology level in which the firm operates. Also the negative effect of intrasectoral externality on small firms when it is positive for large firms and even shows a positive sign when broken down by technology level. In an attempt to find an explanation for this, we will now estimate the model distinguishing by firm size within each technology level. The results are shown in Table 2.

As far as physical capital (k_i) is concerned, it can be seen that the results obtained on aggregate level (Table 1) are reproduced when the estimations are made by sub-sample (Table 2), it being seen that in general terms the greater the size of the firm, the better the return on investment in material goods. This comes about independently of the technology level within which the firm operates (except for knowledge no intensive services, where physical capital is not seen to be significant, and in the case of advanced industries, in which the large firms do not benefit either).

In Table 1 it was seen that firms operating in high-tech sectors obtained greater returns on innovation (i_i), and that this effect occurred especially in knowledge-intensive services. Now, when these firms are broken down by size, it can be seen that this result is mainly due to large firms (column 12), because for small and medium-sized firms innovation is not statistically significant. Generally, it can be seen from Table 2 that industrial firms obtain benefits from their investments in innovation while firms in the service sector do not, with the exception of large knowledge-intensive service firms. Specifically, in the industrial sector it can be seen that the less advanced firms (columns 1 to 3) do not appear to obtain any different returns from their own innovation expenditures according to firm size, since small and large firms show similar coefficients. However, high-tech industries (columns 4 to 6) do clearly show a positive relation to size, i.e. the larger the firm, the more its productivity will increase as a result of investing in innovation. Therefore it appears that the conclusion extracted from Table 1 is maintained, i.e. the greater the technology capital of the sector in which the firm operates, the greater the return on innovation.

Table 2. An IRLS estimation for production function: by technological level and size. Estimation results of empirical model [equation 4].

	LTI			HTI			KNIS			KIS		
	Small (1)	**Medium** (2)	**Large** (3)	**Small** (4)	**Medium** (5)	**Large** (6)	**Small** (7)	**Medium** (8)	**Large** (9)	**Small** (10)	**Medium** (11)	**Large** (12)
k_i	0.0060*** (0.0017)	0.0065*** (0.0020)	0.0134*** (0.0033)	0.0074*** (0.0018)	0.0124*** (0.0027)	0.0044 (0.0039)	-0.0015 (0.0037)	0.0020 (0.0051)	-0.0010 (0.0032)	0.0076*** (0.0022)	0.0151*** (0.0038)	0.0178*** (0.0033)
i_i [(a)]	0.0053*** (0.0017)	0.0038** (0.0019)	0.0052* (0.0027)	0.0043** (0.0019)	0.0056* (0.0029)	0.0155*** (0.0040)	0.0033 (0.0039)	0.0067 (0.0054)	0.0047 (0.0038)	0.0030 (0.0023)	0.0064 (0.0039)	0.0205*** (0.0033)
h_i	0.0050*** (0.0013)	0.0068*** (0.0018)	0.0044* (0.0023)	0.0016 (0.0010)	0.0004 (0.0014)	0.0025 (0.0019)	0.0033* (0.0019)	0.0061* (0.0033)	0.0069*** (0.0019)	-0.0001 (0.0007)	0.0030** (0.0014)	0.0064*** (0.0013)
$S_{i,s}^{INTRA}$	0.0006*** (0.0001)	0.0010*** (0.0001)	0.0007*** (0.0001)	0.0003*** (0.0001)	0.0000 (0.0001)	0.0001 (0.0001)	0.0048*** (0.0005)	0.0035*** (0.0007)	0.0047*** (0.0004)	-0.0001*** (0.0001)	-0.0000 (0.0001)	0.0009*** (0.0001)
$S_{i,s}^{INTER}$	0.0003 (0.0002)	0.0001 (0.0002)	-0.0002 (0.0003)	0.0013*** (0.0004)	0.0020*** (0.0005)	0.0026*** (0.0006)	0.0022*** (0.0004)	0.0019*** (0.0006)	0.0003 (0.0004)	-0.0004*** (0.0002)	-0.0004 (0.0003)	-0.0022*** (0.0003)
Constant	11.4482*** (0.0765)	11.5978*** (0.0839)	11.7524*** (0.1330)	11.1802*** (0.1437)	11.2425*** (0.1716)	10.8202*** (0.2276)	10.2938*** (0.2137)	10.5910*** (0.2924)	10.7754*** (0.1709)	11.3968*** (0.0997)	10.9360*** (0.1718)	11.3998*** (0.1614)
Observations	1,343	1,035	661	1,091	704	467	351	242	617	1,073	553	997
R^2 adjusted	0.1186	0.1616	0.1433	0.0994	0.1173	0.1595	0.2996	0.2500	0.2988	0.0550	0.1629	0.4213

Note: Low and medium-low tech industries (LTI), medium-high and high tech industries (HTI), knowledge no intensive services (KNIS), knowledge-intensive services (KIS).
A group dummy (which takes the value 1 if the firm belongs to a group of companies) is included in all estimations. Standard errors in parenthesis.
[(a)] Innovation expenditures per employee are lagged one period.
*** Significant at 1%, ** significant at 5%, * significant at 10%.

In addition it seems that in those more advanced sectors (HTI and KIS), the larger the firm, the greater the return generated by its innovation expenditure.

Also in Table 1 it was seen that small firms had a greater return on physical capital than on innovation, while in the large ones the opposite was true. However, when this is crossed with technology level it can be seen that the earlier statement is only true of advanced technology sectors (HTI and KIS) and does not apply in low-tech industries (columns 1 to 3), in which, independently of size, the return on physical capital is always higher than on innovation.

With regard to human capital (h_i), it can be seen that the negative sign shown by small and medium-sized firms in Table 1 disappears when size is crossed with sector. Therefore it can be concluded that human capital either has no effect on productivity or its effect is positive and significant. Thus it is seen that human capital is significant for low-tech firms, especially in medium and small industries (columns 1 and 2), and in large and medium-sized service firms (columns 8 and 9). However, in the case of high-tech industries, human capital is not significant at any firm size. Finally, in knowledge-intensive services human capital plays a role in increasing productivity in large and medium-sized firms but not in small ones.

As regards intrasectoral externalities, the result obtained in Table 1 is confirmed and in addition it can be concluded that innovation expenditures carried out by all the other firms in the same sector is important in explaining productivity in low-tech firms (LTI and KNIS) independently of size. In high-tech industries (HTI), however, only the small firms manage to obtain any benefit from intrasectoral externalities, while for the medium-sized and large firms they are not important (columns 5 and 6). This may be due to the fact that these larger-sized firms obtain greater returns from their own innovation expenditures and therefore do not benefit in relative terms in the same way from the innovation carried out by other firms. Small firms, on the other hand, try to make up for their smaller investment effort by taking advantage of any source of innovation from outside the firm. In the case of knowledge-intensive services, the intrasectoral externality has a negative effect on small firms (column 10), which may reflect a competition effect with other small firms in the same sector. Meanwhile the large firms (column 12) are the only ones that increase their productivity through the spending carried out by all the other firms in the same sector. Therefore crossing size with technology level (Table 2) has made it possible to see that the negative sign for the intrasectoral externality in small firms that was obtained in Table 1 is due to those small firms belonging to knowledge-intensive services (column 10).

In line with the result obtained in Table 1, intersectoral externalities in low-tech industries are not significant no matter what size the firms are. In high-tech industries, however, size has a positive effect on the benefit that firms obtain from intersectoral externalities because the greater the size, the more productivity increases. In knowledge-intensive industries the impact is negative in small firms and even more so in large ones. Finally, in knowledge no intensive services it is the smaller (small and medium-sized) firms that see their productivity increase as a result of the innovation expenditure carried out by all the other sectors. Therefore the negative sign for the intersectoral externality in knowledge-intensive services obtained in Table 1 is mainly due to the small and large firms.

5. Conclusions

This paper has studied the extent to which technology level and firm size affect the return that firms obtain from their own investment in innovation and also from the innovations carried out by all other firms (both in the same sector and in all other sectors). To this end a production function was used which included own innovation expenditures and intrasectoral and intersectoral externalities. The estimation method used was the iteratively reweighted least squares, unusual in this area but very useful for obtaining robust estimations in the presence of outliers.

The results coincide with the previous literature since the impact of innovation is positive and statistically significant and also greater for large and high-tech firms. The same happens with physical capital. When comparing both variables it can be seen that the return from physical capital is greater than that from innovation independently of technology level. As far as size is concerned, the same conclusion is reached for small firms, while in the large ones the return on innovation is greater than that on investments in material goods. It must be stressed that human capital has a much greater impact in low-tech firms. As regards intrasectoral externalities, the Spanish firms in the sample manage to benefit from the innovation expenditure carried out by all the other firms in the same sector. This happens especially in low-tech levels, which indicates that this type of firm tries to make up for its smaller investment effort by taking advantage of innovation originating in firms in the same sector. This result points to the existence of a "technology threshold" beyond which firms cease to benefit from the investments in innovation carried out by all the other firms in the same sector. In respect of intersectoral externalities, it has been seen that these play a very ambiguous role since they are important for high-tech industries and knowledge no intensive services but their effect is negative for knowledge-intensive services, and so there appears to be no behaviour pattern depending on technology level. Although in this last case the result is unexpected and counter-intuitive, it might be said that one possible reason could be the great variety of sector typologies found within knowledge-intensive services, such as "postal and mail activities", "other health, social and collective activities" and "other business activities"[14]. Unfortunately this implies a data limitation, since the PITEC classification does not allow for more detailed information on this aspect. Meanwhile it can be concluded that in the case of industry the results are in line with the absorption capacity hypothesis because the greater the technology capital of the sector in which the firm operates – as is the case of high-tech industries – the more advantage is obtained from intersectoral externalities. In the case of knowledge no intensive services, on the other hand, intersectoral externalities may point to the existence of a complementarity of technological efforts between sectors.

Secondly, by crossing technology level with firm size (Table 2) it has been possible to find an explanation for some of the behaviours that at first appeared strange. This is the case with human capital, because once the data were combined it was seen that its effect is always positive or not significant, but never negative. Also, size has a positive influence in the case of services (both KIS and KNIS), since the larger the firm is, the more benefit it obtains from its qualified employees. Crossing technology level and firm size also enabled it to be seen that the returns on innovation expenditures vary according to firm size. Thus it has become clear that the returns from own innovation increase with firm size, but only in high-tech firms. On the other hand, the return obtained from intrasectoral externalities according to the technology level in which the firm operates is not affected by size. Thus firms belonging to less advanced sectors (LTI and KNIS) obtain the most benefit from the innovation expenditure carried out by other firms in the same sector independently of size. Finally, size only appears to have a positive influence on the returns from intersectoral externalities obtained by high-tech

[14] As mentioned earlier, this branch of activity is very heterogeneous and includes businesses ranging from legal services to cleaning.

industries.

On the basis of the results obtained, it can be said that the positive relationship that exists between innovation and productivity should encourage firms to invest more in this area and thereby increase productivity. However, there are a number of difficulties to overcome in order for that innovation to be increased. It needs to be pointed out that Spanish business owners, before investing, take various factors into account including the high risk associated with innovation projects because of the uncertainty they present, and also the difficulty in seizing exclusively all the benefits this innovation generates. It also has to be taken into account that the Spanish business sector is made up of small and medium-sized firms which would perhaps find that raising the finance to carry out this kind of project was no easy task. Also, the Spanish economy is focused more on services than on industry, and services obtain greater returns on innovation (both KIS and KNIS). However, their efforts as regards innovation are much smaller (see Table 4 in the appendix), and therefore policies should offer incentives for these firms to change their behaviour and encourage them to invest in innovation.

Increasing productivity in firm means gaining in competitiveness, which is very important in the globalized world in which we find ourselves. For that reason government efforts should be aimed at incentivizing innovation through help with investment, tax breaks, etc. However, policies should not apply equally to all firms but should be designed for different types of profile. They should, for example, give incentives for high-tech firms to increase their innovation expenditures because these are the firms that best take advantage of this type of investment, while for low-tech firms help aimed at physical capital should not be ruled out. Although large firms are the ones that obtain the most benefit from their investments in innovation, the Spanish business sector is made up of small and medium-sized firms. Therefore one way of increasing the productivity of the economy as a whole may be for tax incentives to take firm size into account, given that carrying out innovation activities does not involve the same effort for all firms independently of size (and therefore turnover). Certain tax deductions, like the one in corporation tax for carrying out R+D+i activities, could take firm size into account in such a way that small firms would be encouraged to carry out more innovation.

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Appendices

Appendix 1. Correspondence table for branches of business activity

Table 3. Correspondence for branches of business activity between PITEC and NACE-93

Branches of business activity PITEC	NACE-93
Low-tech manufacturing industries	
Food products and beverages	15
Tobacco	16
Textile industry	17
Clothing and furriers	18
Leather articles and footwear	19
Wood and cork	20
Paper industry	21
Printing industry	22
Furniture	361
Games and toys	365
Other manufactures	36 (exc. 361, 365)
Recycling	37
Medium-low-tech manufacturing industries	
Coke and refined petroleum products	23
Rubber and plastic products	25
Ceramic tiles and flags	263
Non-metallic mineral products (except tiles and flags)	26 (exc. 263)
Ferrous metallurgic products	271, 272, 273, 2751, 2752
Non-ferrous metallurgic products	274, 2753, 2754
Metal products (except machinery and equipment)	28
Medium-high-tech manufacturing industries	
Chemical products (except pharmaceuticals)	24 (exc. 244)
Pharmaceutical products	244
Machinery and equipment	29
Electrical machinery and apparatus	31
Motor vehicles	34
Building of ships and boats	351
Building aircraft and spacecraft	353
Other transport equipment	35 (exc. 351, 353)
High-tech manufacturing industries	
Office, accounting and computing machinery	30
Electronic components	321
Radio, TV and communications equipments	32 (exc. 321)
Medical, precision and optical instruments	33

Table 3 (continue). Correspondence for branches of business activity between PITEC and NACE-93

Branches of business activity PITEC	NACE-93
Knowledge no intensive services	
Sales and repair of motor vehicles	50
Wholesale trade	51
Retail trade	52
Food and beverage service activities	55
Transport	60, 61, 62
Support activities for transportation	63
Knowledge-intensive services	
Postal and courier activities	641
Telecommunications	642
Financial intermediation	65, 66, 67
Real estate activities	70
Rental and leasing activities	71
Computer activities	722
Other related computer activities	72 (exc.722)
Research and development	73
Architectural and engineering activities	742
Technical testing and analysis	743
Other business activities	74 (exc. 742, 743)
Education	80 (exc. 8030)
Motion picture, video and television programme production	921
Programming and broadcasting activities	922
Other human health and social activities	85, 90, 91, 92 (exc. 921,922), 93

Source: PITEC and OCDE (2001).

Appendix 2. Descriptive statistics

Table 4. Descriptive statistics (2008)

	N	(%)	Averages (thousand of euros)			h
			Y/L	I/L	K/L	
Technology Level [(1) (2)]						
LTI	3,057	33.24%	383.26	2.98	36.19	11.62
HTI	2,273	24.71%	343.08	9.72	16.98	19.85
KIS	2,646	28.77%	156.90	3.76	10.82	39.67
KNIS	1,221	13.28%	226.38	0.59	26.49	14.20
Firm Size [(3)]						
Small	3,888	42.27%	224.58	8.63	14.41	27.37
Medium	2,550	27.73%	281.46	9.21	13.17	20.60
Large	2,759	30.00%	230.10	2.88	20.46	15.95
Technology Level and Firm Size						
LTI						
Small	1,353	14.71%	213.09	4.21	10.89	13.33
Medium	1,039	11.30%	290.68	3.53	12.72	10.76
Large	665	7.23%	424.86	2.71	45.08	9.49
HTI						
Small	1,096	11.92%	199.65	6.89	14.10	21.72
Medium	709	7.71%	279.92	7.43	10.93	18.92
Large	468	5.09%	369.87	10.48	18.58	16.88
KIS						
Small	1,084	11.79%	140.06	18.50	22.05	52.58
Medium	558	6.07%	191.96	23.59	17.77	43.49
Large	1,004	10.92%	155.72	2.66	10.32	23.61
KNIS						
Small	355	3.86%	591.46	3.17	7.24	21.37
Medium	244	2.65%	450.35	4.03	10.60	15.04
Large	622	6.76%	215.65	0.46	27.19	9.77
Total	9,197	100%	233.98	3.54	19.71	22.07

Source: Own based on the PITEC database

Note: The results associated with the labor productivity variable are obtained after adding the information of the sales of all firms in the same technological level and divide by the sum of all employees of all firms at the same technological level. Innovation expenditures per employee and physical capital per employee have been obtained similarly. Human capital is defined as percentage of workers with high education.

(1) Low and medium-low tech industries (LTI), medium-high and high tech industries (HTI), knowledge intensive services (KIS), knowledge no intensive services (KNIS).

(2) Kruskal Wallis test by technological level: 1,452.68***

(3) Kruskal Wallis test by firm size: 152.26***

Firstly it can be seen that the great bulk of firms (33%) clearly falls within the category of low technology level industries, as opposed to the lesser represented knowledge no intensive services (13%). As regards productivity, it can be seen that industrial firms obtain the greatest values, with the less advanced ones (LTI) achieving the highest figures. Here it should be said that the good result for the less advanced industries is due to the excellent results obtained by the coke plant sector and oil refining[15]. However, the table includes average behaviours for sectors which, although classified within the same technology level, are very different from each other. If they are broken down according to size, it can be seen that small firms make up the bulk of the sample (42%). As regards productivity, medium-sized firms are seen to present the highest levels, followed by large firms and finally the smaller firms. Crossing technology level and firm size shows that, within industry (both LTI and HTI), size has a positive effect because the greater the size, the greater the productivity. In services, however, the influence of size varies according to technology level. Thus while in knowledge-intensive services the most productive firms are the medium-sized ones, followed by the large then the small ones, in knowledge no intensive services size has a negative effect, with small firms being those that achieve higher productivity figures.

Secondly, investment in innovation is notably higher in those firms belonging to sectors of high technology levels, in both industry and services. As regards size, it can be seen that medium-sized and small firms invest most in innovation per employee, while large firms present much lower figures. Crossing technology level and size shows that in less advanced industries size influences negatively, since the larger the firm, the less it innovates. However, in more advanced industries size has a positive effect, i.e. the greater the size, the greater the investment in innovation. With services, on the other hand, whether knowledge-intensive or knowledge no intensive, the firms that innovate most are the medium-sized and small and finally, at a considerable distance, the large ones.

[15] Without this branch of business activity, the Y/L average for low-tech industries would fall to 301.2.

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