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12 September 2012

R&D Determinants: Accounting for the Differences between Research and Development*

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September 2012

Abstract

The determinants of R&D are an important topic of industrial economics. The classical Schumpeterian hypotheses about the influence of size and market power have been complemented with the role played by industry determinants, such as demand pull, technological opportunity and appropriability, in determining R&D investments. However, R&D has always been considered as a whole, even though research and development are different activities with different purposes, knowledge bases, people involved and management styles. We take advantage of a new panel database of innovative Spanish firms (PITEC) to distinguish between research and development efforts of firms. We analyze the role jointly played by traditional R&D determinants in driving research and development, accounting for the differences between both activities. Results show that demand pull and appropriability have a higher effect on development, while technological opportunity is more influential for research. Differences are statistically significant, important in magnitude, and robust to the use of different indicators for demand pull, technological opportunity and appropriability and to several robustness checks.

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* We acknowledge support from Fundación Ramón Areces. Part of this paper was developed during the visit of A. López to the Columbia Business School at Columbia University. Errors are ours.

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1. Introduction

A central question in the field of industrial economics is the analysis of the factors leading firms to invest in R&D activities. These activities foster technological progress, and hence they are primary sources of economic growth and welfare (Levin et al., 1987; Cohen and Levin, 1989).

Literature on R&D determinants has mainly focused on two types of factors. The first is the so called "Schumpeterian hypotheses" and is focused on the effects of size and market power on R&D expenditures. The second type of factors includes more fundamental determinants of inter-industry R&D activities (Levin et al, 1985; Cohen and Levin, 1989), such as demand pull, technological opportunity and appropriability.

There is considerable amount of debate in the literature about the role played by these determinants, with theoretical works providing contrasting views and inconclusive empirical evidence. Regarding the empirical literature, previous works show two important shortcomings. First, researchers have failed to take systematic account of all the fundamental sources of variation in R&D behavior in firms and industries (Cohen and Levin, 1989). They have usually performed partial analyses focused on specific determinants of R&D, such as size (Cohen and Klepper, 1996), competition (Aghion et al, 2005), demand pull (Piva and Vivarelli, 2007), technological opportunity (Klevorick et al, 1995) or appropriability (Lerner, 2009). Omission of important and potentially correlated explanatory variables, such as the rest of determinants proposed, may explain the contradictory empirical results (Cohen and Levin, 1989).

A second limitation of this literature is the assumption that R&D is a homogenous activity (Cohen and Levin, 1989). However, research and development are two different activities that differ in purposes, knowledge bases, people involved and management styles (Barge-Gil and López, 2011). More precisely, the main purpose of research is to acquire new knowledge, while the main purpose of development is directed to the introduction of new or improved products or processes (OECD, 2005)., Research is more theoretical in nature (although usually oriented to some practical objective) and is based on analytical knowledge. Development is essentially applied and based on a synthetic knowledge (Asheim and Coenen, 2005). Research needs specialized human capital working relatively independently of the rest of the organization and without much hierarchy, while development shows clear hierarchy and needs generalists able to coordinate with other functional units of the organization (Leifer and Triscari, 1987; Chiesa and Frattini, 2007). As a consequence, these activities are increasingly carried out in different departments, even located in distant places (Chiesa, 2001).

The aim of this paper is to extend previous empirical literature on the determinants of R&D by jointly analyzing the differentiated effect of the relevant factors involved on research and development efforts. By doing this, we take a step towards solving some of the debates raised by previous literature.

We take advantage of a large panel database for Spanish firms that follows the recommendations of the Frascati and Olso Manuals (OCDE, 2002; 2005), and provides detailed information about firms' R&D activities, allowing for differentiation between research and development expenditures. It also provides very detailed information about innovation activities so that indicators for the different determinants proposed in the literature can be defined.

The rest of the paper is organized as follows. Section 2 describes previous research on the determinants of R&D and elaborates on their different influence on research and development. Section 3 describes the data used and the sample of firms. Section 4 sets out a framework for the analysis, describing the econometric details, estimation method applied and the variables used in estimation. Section 5 presents the results. Finally, Section 6 concludes.

2. Previous literature

2.1. Schumpeterian hypotheses

From an industrial economics perspective, most of the earlier works in the field of innovation have focused on testing the 'so-called' Schumpeterian hypotheses: (i) R&D activity increases more than proportionately with firm size, and (ii) R&D activity increases with market concentration (Cohen and Levin 1989).

Regarding the influence of size, several arguments have been put forward to explain a positive relationship between size and R&D. For example, market capital imperfections confer an advantage to large firms as they have more internal funds at their disposal. In addition, R&D is subject to minimum project size so that small firms are prevented to make such investments (Galbraith, 1952) and the existence of economies of scale makes larger investments more profitable. A related reason is the existence of economies of scope. The availability of complementary assets in large firms (such as marketing or financial resources) will confer them an advantage in carrying out R&D activities (Cohen and Levin, 1989). Finally, R&D is risky and many projects fail, so that large firms will be able to spread risks over different projects while smaller firms should focus on one or a few projects only (Rammer et al, 2009).

However, as pointed out by Cohen et al (1987), the above arguments depend on assumptions about the nature and magnitude of transaction and adjustment costs which are rarely tested. Moreover, arguments can also be found supporting that small firms would invest more (in relative terms) in R&D than large firms. For example, one argument is that small firms would be more efficient in performing R&D because they do not suffer from lack of managerial control as large firms do (Holmstrom, 1989). Another argument is that incentives of individual scientists and entrepreneurs would be greater in small firms as they will have more possibilities to benefit from the results of their work.

The empirical evidence, although still subject to some degree of controversy, have resulted on some stylised facts (Cohen and Klepper 1996; Cohen, 2010): (i) the probability of a firm reporting positive R&D effort increases with firm size, (ii) within industries and among R&D performers, R&D rises monotically with firm size across all firm size ranges, and (iii) among R&D performing firms, in most industries there is not a systematic relationship between firm size and elasticity of R&D with respect to firm size across the full range of firm sizes.

Concerning the effect of market power, several arguments justify the belief that more ex ante market power would be associated with more R&D investment. First, Schumpeter (1942) argues that an ex ante oligopolistic market structure made rival behaviour more predictable, thus reducing uncertainty associated with excessive rivalry that undermines the incentive to invest. Second, ex ante market power leads to profits to finance innovation. Finally, Schumpeter also argues that in oligopolistic markets firms could better appropriate the results of their investments.

On the other hand, some authors (see, for example, Arrow, 1962) claim that innovation would partially displace oligopolistic rents, thus reducing incentives to innovate of firms with higher market power. Others authors (Scherer, 1980; Porter, 1990) argue that isolation from competitive pressures could lead to bureaucratic inertia and discourages innovation while active pressure from rivals stimulates innovation.

From an empirical point of view, results are mixed. Some authors have obtained a positive influence of market power on innovation (Crepon et al, 1998; Blundell et al, 1999), while others authors have found a negative one (Geroski, 1990; Harris et al, 2003). As a third possibility, Aghion et al (2005) find that the relationship between product market competition and innovation is an inverted U-shape. In a recent study for the Spanish case, Artes (2009) finds that several different indicators of market concentration positively affect the long term decision of investing on R&D but not the short run one. All in all, what emerges from previous empirical evidence is that market power does not play an important, independent role in affecting R&D (Cohen, 2010).

Theoretical literature suggests that the empirical evidence is not conclusive because the type of R&D has not been considered. In this sense, some theoretical work has been devoted to understand how firm size and market power affect the type of R&D performed. Cohen and Klepper (1996a,b) propose that cost spreading advantage of large firms constitutes an incentive to carry out more incremental projects. Rosen (1991) extends the argument arguing that larger firms can gain relatively more from safer and more incremental R&D projects because they magnify their existing competitive advantage. Kwon (2009) finds that more competition increases the relative expenditure in risky and long term projects but decreases the relative expenditure in basic projects. Finally, Cabral (2003) finds that firms with low market power perform riskier R&D projects. These results are consistent with some empirical evidence showing that larger and incumbent firm tend to pursue relatively more incremental innovation, while small firms with low market power carry out riskier and more radical projects (Christensen and Bower, 1996; Cohen, 2010).

2.2. Demand, technology opportunity and appropriability

A series of papers in the late eighties (Levin et al, 1985; Cohen et al, 1987; Cohen and Levin, 1989; Geroski, 1990) criticises the emphasis on the Schumpeterian hypotheses and recommends to pay more attention to other more industry-specific determinants of R&D, such as demand, technology opportunity and appropriability.

First, the seminal works by Schmookler (1962; 1966) points out the critical importance of demand as a driver of innovation. The Schmookler's underlying assumption is that a common pool of knowledge and capabilities is available to all industries, and therefore large and growing markets provides higher incentives to invest in innovation as these markets offer higher returns for the investment (Cohen and Levin, 1989). Some empirical studies support this view (Cohen et al, 1987; Brouwer and Kleinknecht, 1989), although this support is not as strong as Schmookler thought (Kleinknecht and Verspagen, 1990; Piva and Vivarelli, 2005).

The effect of demand pull on the type of R&D is an under-researched topic. As development is more focused on adapting knowledge to user needs (Leifer and Triscari, 1987), more conducive to new products and more short-term oriented (Barge-Gil and López, 2011), it may be more responsive to market changes. Some indirect evidence of this closer relationship between development and demand pull could be derived from the higher internalization of development (compared to research) in multinational organizations, driven by the desire to match local regulations, standards and tastes (von Zedtwitz and Gassman, 2002).

Second, technological opportunities comprise the set of possibilities for advancing the knowledge frontier and may be measured in terms of the distribution of values of improved production-function or product-attribute parameters that may be attained through R&D or, alternatively, as the distribution of returns to R&D, given demand conditions and the appropriability regime (Klevorick et al, 1995). That is, at prevailing input prices, innovation is “easier” (less costly) in some industries than in others (Cohen and Levin, 1989), so that, more R&D should be found in these industries. Some authors, however, argue that its influence over technological input is not clear. The reason is that technological opportunity may raise the average product of R&D without raising its marginal product, and therefore technological opportunity may not increase R&D investment (Klevorick et al, 1995). Empirical studies have found mixed results for technological opportunities (Cohen et al, 1987; Griliches et al, 1991).

Again, the relationship between opportunities and the type of R&D is an under-researched topic. On the one hand, the absorptive capacity theory (Cohen and Levinthal, 1990) suggests that own research is crucial to benefit from knowledge advances by external parties, suggesting that higher external opportunities may have a greater effect on research rather than on development. Indirect evidence supporting this hypothesis can be found in the internalization patterns of R&D: Research (rather than development) units are located abroad to access frontier knowledge generated in excellence centres (von Zedtwitz and Gassman, 2002). On the other hand, scientific opportunities have a higher effect in increasing the productivity of the more applied R&D projects (Nelson, 1982).

Third, appropriability issues are also of importance. Firms should be able to appropriate returns sufficient to make their investment worthwhile (Levin et al, 1987). However, it should not be taken for granted that more appropriability is related to more innovation effort (Hall and Ziedonis, 2001; Bessen and Maskin, 2009; Lerner, 2009). Many innovations are cumulative and build on previous results achieved by other firms. If these are appropriable, then further innovation investment may be reduced (Nelson, 2006). In addition, the higher the appropriability is, the lower the spillovers are, and therefore R&D investment to absorb them would be reduced (Nelson and Winter, 1982; Cohen and Levinthal, 1989; 1990). Finally, if knowledge is complementary, then spillovers raise the marginal product of own R&D (Levin and Reiss, 1988).

Empirical evidence on the relationship between appropriability and R&D is not conclusive. Some empirical studies have not found a significant effect of appropriability on R&D intensity (Levin et al, 1985), while others find a positive effect only for some industries (see, for example, Mansfield et al, 1981; and Mansfield, 1986).

Taking into account the type of R&D may help to find more conclusive evidence. Kortum and Lerner (1999) suggest that increasing appropriability shifts the innovation activities away from pure research towards more applied, easier to appropriate, activities. Moreover, increasing appropriability may block new lines of research if proprietary pieces of previous knowledge are required. Accordingly, a higher level of appropriability should increase development expenses while its effect on research expenses is unclear.

3. Data and sample of firms

We use information from the *Technological Innovation Panel* (PITEC). The PITEC is a statistical instrument for studying the innovation activities of Spanish firms over time. The data base is developed by the INE (The National Statistics Institute). The data come from the Spanish Community Innovation Survey (CIS). The CIS questionnaire draws from a long tradition of research on innovation, including the Yale survey and the SPRU innovation database (Laursen and Salter, 2006) and it follows guidelines in the Oslo Manual (OCDE, 2005). In addition, the Spanish version of the CIS includes a much more detailed questionnaire in some aspects of firms' innovation processes, following guidelines in the Frascati Manual (OCDE, 2002).

The data base is placed at the disposal of researchers on the FECYT web site.[1] The PITEC contains information for a panel of more than 12,000 firms since 2003. The PITEC consists of several subsamples, the most important of which are a sample of firms with intramural R&D expenditures and a sample of firms with 200 or more employees and. Both subsamples have quite broad coverage. A more detailed description can be found on the FECYT web site.

The PITEC has three main advantages for this study. Firstly and most important, this data base has detailed information about firms' R&D activities. Specifically, it allows the differentiation between research and development expenditures. This information, seldom available, is essential to this study.

Secondly, the PITEC is a CIS-type data base. CIS data are widely used by policy observers to provide innovation indicators and trend analyses and by economists to analyze a variety of topics related to innovation (Cassiman and Veugelers, 2002; Raymond et al., 2010; Czarnitzki and Toole, 2011). Therefore, throughout this study, we use widely accepted innovation indicators and variables. For a review of CIS-based studies, see, for example, van Beers et al. (2008), and Mairesse and Mohnen (2010).

Thirdly, the PITEC is designed as a panel data survey. This fact allows us to mitigate many of the problems related to studies using CIS data, such as the simultaneity between input and outputs, by lagging explanatory variables.

Sample of firms

In this paper, we use information from the PITEC for the period 2005-2009,[2] and we restrict our attention to manufacturing firms.[3] Moreover, our analysis is conducted for firms with positive expenditures in R&D activities for at least one year during the period 2005-2009. Hence, this article is focused on the analysis of firms with experience

[1] http://icono.fecyt.es/pitec/Paginas/por_que.aspx. To observe confidentiality, an anonymized version of the data is available on the web site. The anonymization procedure applied at the PITEC is described on the web page.
[2] Because of enlargements of the sample of firms performing intramural R&D in 2004 and 2005, we do not use the data for the years 2003 and 2004.
[3] R&D performed by manufacturing and service firms shows many differences (see, for example, Sirilli and Evangelista, 1998).

in engaging in R&D activities. The final sample used includes 4,843, 4,811, 4,616, 4,474 and 4,288 firms for the years 2005, 2006, 2007, 2008 and 2009, respectively (see Table 1).

Table 1 shows firms performing R&D (at least one activity), firms performing both research and development, firms performing only research and firms performing only development during the period 2005-2009.[4]

An interesting finding is that less than half of the firms perform both research and development and this percentage is decreasing in time. This finding highlights the importance of carrying out a differentiated analysis of research and development. They are different activities and, in fact, more than half of firms only perform one of them. With respect to firms specialized in one activity, firms performing only development activities are more common than those performing only research. The percentage of firms specialized in each activity is increasing in time.

Table 1. Sample Statistics

	2005	**2006**	**2007**	**2008**	**2009**
Firms in the sample	4,843	4,811	4,616	4,478	4,288
Firms with R&D	4,355	3,898	3,534	3,248	2,925
Firms with both R&D[1]	1,880 (43.2%)	1,649 (42.3%)	1,466 (41.5%)	1,357 (41.8%)	1,153 (39.4%)
Firms with only R[1]	1,042 (23.9%)	910 (23.3%)	840 (23.8%)	784 (24.1%)	759 (25.9%)
Firms with only D[1]	1,433 (32.9%)	1,339 (34.4%)	1,228 (34.7%)	1,107 (34.1%)	1,013 (34.6%)

[1] Number of firms and percentage of firms with respect to the number of firms with R&D.

4. A framework for the analysis

4.1. The basic framework

As we said in the introduction, the aim of this paper is to analyze the differentiated role of the traditionally considered determinants of research and development efforts.

[4] As it can be seen, the number of R&D performers decreases during the period 2005-2009 in the whole sample. This decrease is mainly due to firms which report performing R&D occasionally.

Specifically, we focus on the impact of firm size, market power, demand pull factors, technological opportunity and appropriability conditions.

Variables used

Our dependent variables are research and development intensities. We define these variables as the ratio between research expenditures and number of employees in logs (*RInt*) and the ratio between development expenditures and number of employees in logs (*DInt*).[5]

With respect to the explanatory variables employed, firstly, we define firm size (*Size*) as the logarithm of number of employees. Size squared (*SizeSq*) is considered to allow for non-linear elasticity.

Secondly, we define market power (*MarkPower*) as the log of share of firm sales in total industry sales.[6] This indicator of market power using CIS data has been previously used by other authors (Hussinger, 2008; Raymond et al., 2010). Again, market power squared is considered to allow for non-linear elasticity (*MarkPowerSq*).

Thirdly, we measure demand pull (*DemPull*) by using the mean of innovative sales at the industry level. Innovative sales are defined as the weight of total sales from innovations new to the firm's market or new to the firm over total sales. As a robustness check, we use an alternative measure for demand pull (*DemPull_b*) introduced by Raymond et al. (2010). This variable is a dummy variable that equals 1 if the firm rates at least one of the two following objectives of innovation as "high importance" (highest mark on a 0–3 Likert scale): open up new markets and extend product range; and 0 otherwise.

Fourthly, as a proxy for technological opportunity (*TechOpp*), following Raymond et al. (2010), we use an industry-level measure of the importance of universities and research institutes as sources of information for innovation. In doing this, first we define a dummy variable that takes the value 1 if the firm considers universities or research institutes a very important source of information for innovation, and zero otherwise.

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[5] Specifically, this differentiation between research and development expenditures refers only to current R&D expenditures. In our main specification, we assume that these weights can be extended to total R&D expenditures (including both current and capital expenditures). In our sample, current R&D expenditures account for approximately 80% of total R&D expenditures.

[6] Throughout this paper industry level is defined at 4-digit NACE.

Then, we calculate the mean of this dummy variable at the industry level. As a robustness check, we use an alternative measure for technological opportunity (*TechOpp_b*): a dummy variable identifying firms belonging to high-tech industries according to the OCDE classification of manufacturing industries (see OCDE, 2005).[7] A dummy variable for industries where the vigor of advance of underlying scientific and technological knowledge has usually been employed in empirical studies (Cohen and Levin, 1989)

Finally, we measure appropriability (*Appr*) using the mean of the weight of sales from innovations new to the firm's market over total innovative sales at the industry level. Innovative sales include sales from products new to the firm's market or new to the firm. This latter case may be considered the result of imitations of innovations already introduced in the firm's market. Therefore, the higher the value of this variable is, the lower the weight of imitations on total innovative sales at the industry level, and hence, the higher the industry level of appropriability of innovation results. Additionally, we use information of legal methods for protecting innovation as an indicator of appropriability (*Appr_b*) (see Veugelers and Cassiman, 2005). Specifically, we define this variable as the percentage of firms having applied for patents at the industry level. Accordingly, the higher this percentage is, the higher the level of legal protection at the industry.[8]

Econometric specification

Our starting point is to assume that the determinants previously defined have an impact on both research and development, but this impact should be different. Hence, our specification is given by the following set of two equations to be estimated:

$$RInt_{it} = \alpha_{1r}Size_{it-1} + \alpha_{2r}SizeSq_{it-1} + \alpha_{3r}MarkPower_{it-1} + \alpha_{4r}MarkPowerSq_{it-1} + \alpha_{5r}Dpull_{it-1} + \alpha_{6r}TechOpp_{it-1} + \alpha_{7r}Appr_{it-1} + \mu_{ir} + \varepsilon_{itr} \quad (1)$$

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[7] High-tech industries are the following: aircraft, spacecraft, pharmaceuticals, office machinery, radio and TV equipment, and medical and optical instruments.

[8] The main difference between legal protection methods and other methods (e.g. secrecy) is that legal methods provide two types of exclusion. First, legal protection prevents other firms from imitating innovations. Second, these methods prevents from commercializing their own independent success in the same innovations. Secrecy only provides the first type of exclusion. Stronger patent protection increases patent propensity, even if secrecy was a preferred alternative when patents protection was weaker. As patents protect against independent innovation success of other firms and secrecy does not, incentives for innovation diminish (Kwon, 2012).

$$DInt_{it} = \alpha_{1d} Size_{it-1} + \alpha_{2d} SizeSq_{it-1} + \alpha_{3d} MarkPower_{it-1} + \alpha_{4d} MarkPowerSq_{it-1} + \alpha_{5d} Dpull_{it-1} + \alpha_{6d} TechOpp_{it-1} + \alpha_{7d} Appr_{it-1} + \mu_{id} + \varepsilon_{itd} \quad (2)$$

where subscript *i* refers to firm, subscript *t* refers to time. As control variables we also include a set of year dummies and a dummy variable identifying those firms performing R&D continuously (*ContR&D*).[9]

We use the seemingly unrelated regressions (SUR) approach to estimate the system of equations given by expressions (1) and (2).[10] This approach allows for correlated errors across equations. For example, correlation between the errors in equations (1) and (2) can arise from omitted variables that we cannot include in the specification. In this sense, both research and development can be correlated with unobserved factors.

In addition, to avoid endogeneity and simultaneity problems, industry-level variables for each firm are calculated excluding the firm in question and explanatory variables are lagged by one period. Therefore, we explain research and development intensities in terms of past firm or industry characteristics. This reduces our sample to an unbalanced panel of four years and 17,784 observations.

4.2. Two-part model

Dependent variables in equations (1) and (2) can be equal to zero (i.e., firm *i* at year *t* may not have expenditures in research and/or development activities). Therefore, the basic model does not allow us to distinguish between the "performance" decision and the "intensity" decision. We deal with this issue by estimating a two-part model.

First, we analyze the determinants of the decision to undertake research and development. In doing this, we define two new dependent variables, specifically, a dummy variable identifying those firms undertaking research activities (*RDec*) and a dummy variable identifying those firms undertaking development activities (*DDec*).

Now, in this first step, our specification is given by the following two equations:

$$RDec_{it} = \sigma_{1r} Size_{it-1} + \sigma_{2r} SizeSq_{it-1} + \sigma_{3r} MarkPower_{it-1} + \sigma_{4r} MarkPowerSq_{it-1} + \sigma_{5r} Dpull_{it-1} + \sigma_{6r} TechOpp_{it-1} + \sigma_{7r} Appr_{it-1} + \rho_{ir} + \theta_{itr} \quad (3)$$

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[9] We define continuous R&D performers as those firms which present a positive amount spent on R&D each year in the period 2005-2009.

[10] For a further discussion of the estimation of a set of SUR equations with panel data, see Baltagi (2005), Chapter 6.

$$DDec_{it} = \sigma_{1d} Size_{it-1} + \sigma_{2d} SizeSq_{it-1} + \sigma_{3d} MarkPower_{it-1} + \sigma_{4d} MarkPowerSq_{it-1} + \sigma_{5d} Dpull_{it-1} + \sigma_{6d} TechOpp_{it-1} + \sigma_{7d} Appr_{it-1} + \rho_{id} + \theta_{itd} \quad (4)$$

Again, we estimate equations (3) and (4) using the SUR approach for the whole sample of firms.

Second, we focus on the determinants of research and development intensities (equations 1 and 2), restricting our attention to the subsample of firms with positive expenditures in both activities.

5. Results

In this section, first the basic (one step) model is estimated. We also analyze the robustness of the results to different measures of demand pull, technological opportunity and appropriability. Next, a two-part model is estimated. Again, different robustness checks are presented.

5.1. Basic specification

Table 2 shows the estimated marginal effects of the independent variables for basic models.

Size elasticities of research and development intensities decrease with firm size. For example, for firms with 20 employees, size elasticities are 0.33 and 0.18 for research and development, respectively. These figures are lower (0.03 and 0.02, respectively) for firms with 200 employees. Finally, for firms with 1000 employees, an increase in firm size implies a decrease in investment (elasticities of -0.17 for research and -0.09 for development). However, some caveat should apply to these results. As we said in the previous section, the basic specification does not allow us to distinguish between the "performance" decision and the "intensity" decision. As we will show when estimating the two- part model (see section 4.2), the likelihood of doing any of the investments is positively affected by size while the intensity of investments shows an inverted U shape relationship with size.

Market power elasticity of investment shows a different pattern for research and development, usually with quite small magnitudes. For research, elasticity is always negative, although it tends to zero for higher values of market power. For development, however, elasticity is positive for firms with little market power (0.02 for firms with

0.1% of industry sales) and negative for firms with great market power (-0.29 for firms with 10% of industry sales).

Table 2. Determinants of research and development intensities
Basic specification

	RInt (1)		*Dint* (2)	
Size	0.713***	(0.054)	0.387***	(0.054)
SizeSq	-0.064***	(0.006)	-0.034***	(0.006)
MarkPower	-0.136***	(0.044)	0.182***	(0.044)
MarkPowerSq	0.008	(0.005)	-0.024***	(0.004)
DemPull	0.973***	(0.138)	1.758***	(0.140)
TechOpp	1.718***	(0.177)	0.542***	(0.179)
Appr	0.419***	(0.083)	1.016***	(0.085)
ContR&D	2.622***	(0.044)	3.078***	(0.042)
Year06	0.711***	(0.028)	0.910***	(0.029)
Year07	0.442***	(0.028)	0.646***	(0.029)
Year08	0.296***	(0.028)	0.383***	(0.029)
Observations	17,784		17,784	

Marginal effects are reported. Standard errors in parentheses.
*significant at 10%, ** significant at 5%, *** significant at 1%.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level.

Demand pull shows a positive effect for both research and development, with the coefficient for development almost doubling that for research. A movement from the lower to the upper quartile of the share of innovative sales in the 4-digit industry is associated with an increase in research intensity per employee between 9-16% and with an increase of development intensity per employee between 19-26%.[11]

Technological opportunity also has a positive effect on both research and development. Here, the coefficient for research is three times higher than the coefficient for development. A movement from the lower to the upper quartile of the distribution of this variable implies an increase in research expenses per employee between 12-18% and an increase of development expenses per employee between 2-8%.

[11] These effects are calculated using the 95% confidence interval for coefficients.

Appropriability also has a positive effect for both research and development, although this effect is higher in the case of development intensity. A movement from the lower to the upper quartile of the distribution of this variable is associated with an increase in research expenses per employee between 4-10% and with an increase of development expenses per employee of 14-20%.

These results are robust to the use of alternative measures for demand pull, technology opportunity and appropriability. Table 3 presents these robustness checks.

When defining an alternative measure for demand pull (*DemPull_b)*, this factor again has a positive effect on both research and development, with the coefficient higher for development. In this case, the interquartile variation is associated with an increase in research expenses per employee between 22-29% and with an increase of development expenses per employee between 25-32%.[12]

We define a dummy variable identifying high-tech firms as an alternative measure for technological opportunity (*TechOpp_b*). We find that belonging to a high-tech sector increases research expenses per employee by 114-139% and development expenses per employee by 64-88% (compared to a firm outside the high-tech sector).

Finally, the alternative measure for appropriability (*Appr_b*) has a positive effect on development intensity. However, this variable loses significance for research intensity. The interquartile variation of this variable is associated with an increase of development expenses per employee of 25-32%.

[12] The difference is not statistically significant. This is not surprising as this indicator uses subjective valuations, thus introducing measurement error.

Table 3. Determinants of research and development intensities. Basic specification

	Alternative variable for Demand Pull				Alternative variable for Technological Opportunity				Alternative variable for Appropriability			
	RInt (1)		*Dint* (2)		*RInt* (3)		*Dint* (4)		*RInt* (5)		*Dint* (6)	
Size	0.520***	(0.056)	0.239***	(0.055)	0.723***	(0.054)	0.374***	(0.053)	0.768***	(0.053)	0.424***	(0.053)
SizeSq	-0.046***	(0.006)	-0.023***	(0.006)	-0.068***	(0.006)	-0.035***	(0.006)	-0.069***	(0.006)	-0.041***	(0.006)
MarkPower	-0.146***	(0.044)	0.183***	(0.044)	-0.066	(0.045)	0.233***	(0.044)	-0.123***	(0.044)	0.215***	(0.044)
MarkPowerSq	0.012**	(0.005)	-0.020***	(0.004)	0.005	(0.005)	-0.026***	(0.004)	0.006	(0.005)	-0.024***	(0.004)
DemPull					0.525***	(0.139)	1.454***	(0.141)	1.016***	(0.140)	1.575***	(0.141)
DemPull_b	1.467***	(0.097)	1.657***	(0.098)								
TechOpp	1.629***	(0.177)	0.449**	(0.179)					1.776***	(0.177)	0.496***	(0.179)
TechOpp_b					1.267***	(0.064)	0.762***	(0.062)				
Appr	0.334***	(0.083)	0.946***	(0.085)	0.314***	(0.083)	0.934***	(0.085)				
Appr_b									0.007	(0.137)	1.949***	(0.138)
ContR&D	2.593***	(0.044)	3.055***	(0.042)	2.525***	(0.044)	3.016***	(0.042)	2.627***	(0.044)	3.068***	(0.042)
Year06	0.722***	(0.028)	0.931***	(0.029)	0.711***	(0.028)	0.909***	(0.029)	0.707***	(0.028)	0.836***	(0.029)
Year07	0.484***	(0.028)	0.688***	(0.029)	0.438***	(0.028)	0.641***	(0.029)	0.445***	(0.028)	0.609***	(0.029)
Year08	0.342***	(0.028)	0.423***	(0.029)	0.288***	(0.028)	0.377***	(0.029)	0.307***	(0.028)	0.384***	(0.029)
Observations	17,784		17,784		17,784		17,784		17,784		17,784	

Marginal effects are reported. Standard errors in parentheses. *significant at 10%, ** significant at 5%, *** significant at 1%.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 (*Size*, *MarkPower*, *MarkPowerSq*, *TechOpp* and *Appr*) and the 0.05 (*SizeSq*) levels. Test of equality of estimated coefficients of *DemPull_b* across equations (1) and (2) does not allow us to reject the null hypotheses of equality of coefficients.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp_b* and *Appr* across equations (3) and (4) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp* and *Appr_b* across equations (5) and (6) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level.

5.2. Two-part model

In this section, we present the estimation of a framework distinguishing between the determinants of the decision to invest in research and/or development; and the determinants of the intensity of these investments for those firms active in both activities. Table 4 shows the results.

Firm size has a positive and significant effect on the probability of both decisions. For firms with 20 employees, a 1% increase in size implies an increase of 6 percentual points on the probability of performing research activities and an increase of 5 percentual points on the probability in the likelihood of performing research activities. As expected, the impact of size decreases as size grows, but still remains positive. For firms with 200 employees, these figures are 3 percentual points for both research and development. For firms with 1,000 employees, a 1% increase in size is associated with an increase of 0.5 percentual points on the probability of performing research, while the effect on development activities remains higher (2 percentual points).

In this case, results for the determinants of intensities are quite different. For firms with 20 employees, size elasticities of intensities are 0.79 and 0.72 for research and development, respectively. However, for firms with 200 employees, these figures are -0.28 and -0.24. That is, for small firms, an increase in size is associated with an increase in both research and development expenses per employee. However, this effect reverts as firms grow, the turning point being around 110 employees.[13]

Market power has a small (although significant) effect on the probability of both decisions. When analyzing intensities, market power has an effect similar to that of firm size. For firms with little market power, an increase in this variable is associated with an increase in both research and development expenditures per employee. For example, a firm whose sales represent 0.1% of its industry sales shows an elasticity of 0.06 for research and 0.11 for development. However, this positive effect reverts as firms gain market power, the turning point being around 0.3% of sales for research and 0.6% of sales for development.

[13] The first of these results support the Stylized Fact 1 by Cohen and Klepper (1996). However, the second one shows new evidence on their stylized facts 2 and 3 by taking account of varying elasticities, although in a different level of analysis (inter-industry vs. intra-industry).

Table 4. Determinants of research and development
Two part model

	Determinants of R and D decisions				Determinants of R and D intensities			
	RDec (1)		*DDec* (2)		*RInt* (3)		*Dint* (4)	
Size	0.102***	(0.007)	0.060***	(0.007)	2.188***	(0.039)	1.970***	(0.040)
SizeSq	-0.007***	(0.001)	-0.003***	(0.001)	-0.233***	(0.004)	-0.209***	(0.004)
MarkPower	-0.025***	(0.006)	0.017***	(0.006)	0.187***	(0.032)	0.245***	(0.032)
MarkPowerSq	0.002***	(0.001)	-0.002***	(0.001)	-0.027***	(0.003)	-0.030***	(0.003)
DemPull	0.090***	(0.018)	0.177***	(0.018)	1.993***	(0.104)	2.461***	(0.103)
TechOpp	0.133***	(0.023)	0.010	(0.023)	2.478***	(0.124)	1.509***	(0.123)
Appr	0.031***	(0.011)	0.084***	(0.011)	1.220***	(0.068)	1.915***	(0.068)
ContR&D	0.324***	(0.006)	0.379***	(0.005)	0.790***	(0.029)	0.795***	(0.029)
Year06	0.100***	(0.004)	0.129***	(0.004)	0.269***	(0.029)	0.140***	(0.030)
Year07	0.064***	(0.004)	0.092***	(0.004)	0.300***	(0.032)	0.099***	(0.030)
Year08	0.039***	(0.004)	0.055***	(0.004)	0.298***	(0.032)	-0.035	(0.030)
Observations	17,784		17,784		5,501		5,501	

Marginal effects are reported. Standard errors in parentheses.
*significant at 10%, ** significant at 5%, *** significant at 1%.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Tests of equality of estimated coefficients of *Size*, *SizeSq*, *DemPull*, *TechOpp* and *Appr* across equations (3) and (4) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Test of equality of estimated coefficients of *MarkPower* and *MarkPowerSq* across equations (3) and (4) does not allow us to reject the null hypotheses of equality of coefficients.

Demand pull positively affects both the decision and the intensity of both research and development, but its effect is always higher for development activities. Its interquartile variation is associated with an increase of 0.7-1.6 percentual points in the probability of performing research and 1.8-2.7 percentual points in the probability of performing development. For those firms active in both activities, the interquartile variation is associated with an increase of 22-27% of research expenses per employee and an increase of 28-33% of development expenses per employee.

Technological opportunity positively affects the probability of performing research, and its interquartile variation is associated with an increase of 0.8-1.6 percentual points of this probability. However, this variable has no effect on development decisions. For those performing both activities, technological opportunity has a positive and significant effect on both intensities. In this case, the interquartile variation is associated with an increase of 20-25% of research expenses per employee and an increase of 11-16% of development expenses per employee.

Finally, appropriability positively affects both the decision and intensity of both research and development. However, its effect is much higher for development. Its interquartile variation is associated with an increase of 0.2-0.9 percentual points in the probability of performing research and 1.1-1.8 percentual points in the probability of performing development. For those doing both activities, the interquartile variation is associated with an increase of 19-24% of research expenses per employee and an increase of 31-36% of development expenses per employee.

As we did for the basic specification, we analyze the robustness of these results to the use of alternative measures for demand pull, technology opportunity and appropriability. Table 5 shows the results for the determinants of research and development decisions, while Table 6 focuses on intensities.

Firstly, regarding the effects of demand pull, the alternative measure used for this variable has a positive effect on both the decision and the intensities. This effect is slightly higher for development expenditures: an interquartile variation of demand pull increases likelihood of performing research by 2.2-3.1 percentual points and increases the research expenses per employee by 33-38%, while it increases likelihood of performing development by 2.3-3.2 percentual points and the development expenses per employee by 35-40%.

Secondly, the alternative measure employed for technological opportunity shows that belonging to a high-tech sector increases the probability of performing research by 8-11 percentual points and increases the research expenses per employee by 94-108%. Also, this variable increases the probability of performing development by 1-4 percentual points and development expenses per employee by 92-106%.

Finally, results for the alternative measure used for appropriability present some differences. Interestingly, this variable has a negative effect on the decision of performing research activities. This result suggests that a strong patent protection may act as a barrier to this type of activity. However, this variable has a positive effect on development decisions. In this case, the interquartile variation of this indicator is associated with an increase by 2.4-3.5 percentual points in the probability of performing development activities. When analyzing research and development intensities, we find that this variable has a positive effect on both intensities, although this effect is higher in the case of development intensity. Specifically, the interquartile variation is associated with an increase of 10-16% of research expenses per employee and an increase of 17-23% of development expenses per employee.

5.3. Additional robustness checks

We apply two additional robustness checks to verify our results. Firstly, we test the sensibility of our results to the exclusion of firms belonging to industries (at 4-digit NACE) with few observations per year. In doing this, we drop firms belonging to industries with less than 5 observations.[14] Tables A1 and A2 in Appendix 1 show the results for the basic model and two-part model, respectively. We find that the results are very similar to those presented before, with one exception for the first part in the research equation. In this case, we find that appropriability has a negative, although not significant, effect on the research decision.[15]

Secondly, so far, we have considered both occasional and continuous R&D performers in our analysis. We have controlled for this fact including a dummy variable identifying continuous R&D performers in our estimates. Now, we test the sensibility of our results, restricting our attention to the sub-sample of continuous R&D performers. Tables A3 and A4 in Appendix 1 show the results for the basic model and two-part model, respectively. The main conclusion is that differences between the determinants of research and development hold, and, in some cases, these differences are more important. However, we find that the magnitude of coefficients is, in general, lower. In fact, we find that demand pull no longer has a significant effect on research decisions, while technological opportunity is not significant for development.[16]

[14] 449 observations are deleted.

[15] Results (not reported here but available upon request) using the alternative variables show that the negative and significant effect of the percentage of firms having applied for patents (variable *Appr_b*) on research holds in this subsample.

[16] Results (not reported here but available upon request) using the alternative variables show that the negative and significant effect of the percentage of firms having applied for patents (variable *Appr_b*) on research holds in this subsample.

Table 5. Determinants of research and development. Two part model: Determinants of R and D decisions

	Alternative variable for Demand Pull				Alternative variable for Technological Opportunity				Alternative variable for Appropriability			
	RDec (1)		*DDec* (2)		*RDec* (3)		*DDec* (4)		*RDec* (5)		*DDec* (6)	
Size	0.081***	(0.007)	0.046***	(0.007)	0.103***	(0.007)	0.059***	(0.007)	0.108***	(0.007)	0.061***	(0.007)
SizeSq	-0.005***	(0.001)	-0.002*	(0.001)	-0.007***	(0.001)	-0.003***	(0.001)	-0.008***	(0.001)	-0.003***	(0.001)
MarkPower	-0.026***	(0.006)	0.018***	(0.006)	-0.020***	(0.006)	0.020***	(0.006)	-0.024***	(0.006)	0.020***	(0.006)
MarkPowerSq	0.002***	(0.001)	-0.002***	(0.001)	0.002**	(0.001)	-0.002***	(0.001)	0.002**	(0.001)	-0.002***	(0.001)
DemPull					0.056***	(0.018)	0.163***	(0.018)	0.099***	(0.018)	0.157***	(0.018)
DemPull_b	0.156***	(0.013)	0.159***	(0.013)								
TechOpp	0.122***	(0.023)	0.001	(0.023)					0.142***	(0.023)	0.004	(0.023)
TechOpp_b					0.092***	(0.008)	0.029***	(0.008)				
Appr	0.020*	(0.011)	0.078***	(0.011)	0.023**	(0.011)	0.080***	(0.011)				
Appr_b									-0.037**	(0.018)	0.192***	(0.018)
ContR&D	0.321***	(0.006)	0.377***	(0.005)	0.317***	(0.006)	0.376***	(0.005)	0.325***	(0.006)	0.377***	(0.005)
Year06	0.101***	(0.004)	0.131***	(0.004)	0.100***	(0.004)	0.129***	(0.004)	0.101***	(0.004)	0.122***	(0.004)
Year07	0.069***	(0.004)	0.096***	(0.004)	0.064***	(0.004)	0.092***	(0.004)	0.065***	(0.004)	0.089***	(0.004)
Year08	0.044***	(0.004)	0.059***	(0.004)	0.039***	(0.004)	0.055***	(0.004)	0.041***	(0.004)	0.055***	(0.004)
Observations	17,784		17,784		17,784		17,784		17,784		17,784	

Marginal effects are reported. Standard errors in parentheses. *significant at 10%, ** significant at 5%, *** significant at 1%.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Test of equality of estimated coefficients of *DemPull_b* across equations (1) and (2) does not allow us to reject the null hypotheses of equality of coefficients.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp_b* and *Appr* across equations (3) and (4) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp_b* and *Appr_b* across equations (5) and (6) allow us to reject the null hypotheses of equality of coefficients at the 0.01 (*Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *TechOpp_b* and *Appr_b)* and the 0.05 (*DemPull*) levels.

Table 6. Determinants of research and development. Two part model: Determinants of R and D intensities

	Alternative variable for Demand Pull				Alternative variable for Technological Opportunity				Alternative variable for Appropriability			
	RIntc (1)		*DIntc* (2)		*RIntc* (3)		*Dint* (4)		*RInt* (5)		*Dint* (6)	
Size	2.012***	(0.041)	1.833***	(0.041)	2.198***	(0.039)	1.930***	(0.040)	2.307***	(0.039)	2.152***	(0.039)
SizeSq	-0.219***	(0.004)	-0.199***	(0.004)	-0.236***	(0.004)	-0.207***	(0.004)	-0.245***	(0.004)	-0.227***	(0.004)
MarkPower	0.155***	(0.032)	0.207***	(0.032)	0.245***	(0.032)	0.323***	(0.032)	0.195***	(0.033)	0.274***	(0.032)
MarkPowerSq	-0.021***	(0.003)	-0.023***	(0.003)	-0.029***	(0.003)	-0.033***	(0.003)	-0.028***	(0.003)	-0.032***	(0.003)
DemPull					1.530***	(0.105)	2.090***	(0.104)	1.916***	(0.105)	2.390***	(0.103)
DemPull_b	2.089***	(0.074)	2.181***	(0.074)								
TechOpp	2.288***	(0.124)	1.286***	(0.123)					2.531***	(0.125)	1.646***	(0.123)
TechOpp_b					1.210***	(0.067)	1.829***	(0.068)				
Appr	1.163***	(0.067)	1.839***	(0.068)	1.010***	(0.034)	0.990***	(0.034)				
Appr_b									0.819***	(0.101)	1.276***	(0.099)
ContR&D	0.744***	(0.029)	0.752***	(0.029)	0.745***	(0.029)	0.731***	(0.029)	0.806***	(0.029)	0.802***	(0.029)
Year06	0.314***	(0.029)	0.231***	(0.029)	0.287***	(0.029)	0.149***	(0.030)	0.254***	(0.030)	0.101***	(0.030)
Year07	0.366***	(0.032)	0.195***	(0.030)	0.315***	(0.031)	0.119***	(0.030)	0.298***	(0.032)	0.091***	(0.030)
Year08	0.357***	(0.032)	0.050*	(0.030)	0.292***	(0.032)	-0.032	(0.030)	0.324***	(0.032)	-0.013	(0.030)
Observations	5,501		5,501		5,501		5,501		5,501		5,501	

Marginal effects are reported. Standard errors in parentheses. *significant at 10%, ** significant at 5%, *** significant at 1%.

Tests of equality of estimated coefficients of *Size*, *SizeSq*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Tests of equality of estimated coefficients of *MarkPower*, *MarkPowerSq* and *DemPull_b* across equations (1) and (2) do not allow us to reject the null hypotheses of equality of coefficients.

Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *DemPull* and *Appr* across equations (3) and (4) allow us to reject the null hypotheses of equality of coefficients at the 0.01 (*Size*, *SizeSq*, *DemPull* and *Appr)* and the 0.05 (*MarkPower)* levels. Test of equality of estimated coefficients of *MarkPowerSq* and *TechOpp_b* across equations (3) and (4) does not allow us to reject the null hypotheses of equality of coefficients.

Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *DemPull*, *TechOpp* and *Appr_b* across equations (5) and (6) allow us to reject the null hypotheses of equality of coefficients at the 0.01 (*Size*, *SizeSq*, *DemPull*, *TechOpp* and *Appr_b)* and the 0.05 (*MarkPower*) levels. Test of equality of estimated coefficients of *MarkPowerSq* across equations (5) and (6) does not allow us to reject the null hypotheses of equality of coefficients.

6. Discussion and conclusions

The aim of this paper has been to jointly analyze the role played by the different R&D determinants found in the literature in driving research and development, accounting for the differences between both activities.

We find that, when research and development are differentiated and the Schumpeterian determinants are analyzed together with the more fundamental determinants of R&D (demand pull, technological opportunity and appropriability), empirical results become more conclusive.

The effect of firm size depends on the analysis performed. In this case, it is crucial to distinguish between the "performance" decision and the "intensity" decision. Firm size has a positive and significant effect on the decision of investing in both research and development. However, its effect on the intensity of the investment (for those firms active in these activities) shows a U-inverted relationship. The effect of market power is found to be quite low in both research and development, in line with most of the results from previous empirical literature. Regarding their differentiated effect on research and development, results show that effect of size and market power is usually higher on development than on research. This result agrees with the theoretical results that large, oligopolistic firms gain relatively more from incremental and safer projects (Rosen, 1991; Cabral, 2003; Cohen, 2010).

Demand pull shows higher effects (coefficient**s** are usually doubled in size) in driving development than research, although both investments are sensitive to demand pull. This result highlights the fact that development is more focused on adapting knowledge to user needs and allows for quicker answers to market demands (Leifer and Triscari, 1987; Barge-Gil and López, 2011).

Regarding technological opportunity, we find that this variable has a much higher effect on research (coefficients tripled in size) suggesting that research is crucial to benefit from such opportunities, in line with arguments provided by the absorptive capacity theory (Cohen and Levinthal, 1990)

Finally, appropriability shows a positive effect in driving development. However, its relationship with research is not clear. On the one hand, the decision to perform research may be negatively affected by appropriability. This is specially the case when legal appropriability is analyzed. On the other hand, research intensity is however positively affected by appropriability. These results shed some light on debates from previous theoretical and empirical literature. Some authors have warned against the potential damaging effects of higher appropriability on R&D (Bessen and Maskin, 2009; Kwon; 2012). Our results are consistent with their arguments. We contribute to the literature by showing that the negative effect of appropriability on R&D arises from its negative influence on the likelihood of performing research activities. As Hall and Ziedonis (2001) have highlighted, if innovation is cumulative and patent rights are very strong, firms are concerned about being held up by external patent owners so that they engage in patent portfolio races and use patent counts as the unit of currency. That is, only firms with “deep pockets” are able to conduct research activities. This logic could explain why the likelihood of performing research activities is lower when legal appropriability increases while research intensity is still positively affected.

In this paper, we contribute to the empirical literature on innovation by improving our understanding of the forces driving research and development in industry. In addition, our results are helpful for policy design aiming at define initiatives to encourage these activities. More precisely, our results highlight the potential of demand policies to increase development expenses and of supply policies to increase research expenses, while casting some doubts on the role of the patent system to foster research activities.

This work is not without limitations which also constitute opportunities for future research. First, our sample is composed of R&D performers. It would be interesting to extend these results to a broader sample of firms. Unfortunately, our database does not allow us to properly deal with this selection issue. Second, we analyze the Spanish case, where a low degree of R&D intensity is combined with a high relative orientation to research (Barge-Gil and López, 2011). Evidence from other countries on the differentiated determinants of research and developed might help to develop more general empirical evidence.[17] Third, how the different determinants of research and development interact is an unexplored issue which deserves further research.

[17] Although previous research using CIS data finds that results for Spain do not seem to be different from the results for other European countries (see Griffith et al., 2006, for evidence on the relationship between innovation and productivity, and Abramovsky et al., 2009, for evidence on the determinants of co-operative innovative activity).

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Appendix 1. Additional results

Table A1. Determinants of research and development intensities
Basic specification. Robustness check 1

	RInt (1)		*Dint* (2)	
Size	0.790***	(0.045)	0.452***	(0.056)
SizeSq	-0.083***	(0.005)	-0.036***	(0.007)
MarkPower	-0.146***	(0.037)	0.087*	(0.047)
MarkPowerSq	0.010**	(0.004)	-0.014***	(0.005)
DemPull	0.859***	(0.136)	1.996***	(0.153)
TechOpp	3.618***	(0.172)	0.638***	(0.200)
Appr	0.187**	(0.086)	0.836***	(0.090)
ContR&D	2.549***	(0.030)	3.075***	(0.044)
Year06	0.736***	(0.030)	0.896***	(0.029)
Year07	0.435***	(0.029)	0.627***	(0.028)
Year08	0.295***	(0.029)	0.375***	(0.029)
Observations	17,335		17,335	

Marginal effects are reported. Standard errors in parentheses.
*significant at 10%, ** significant at 5%, *** significant at 1%.
Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level.

Table A2. Determinants of research and development
Two part model. Robustness check 1

	Determinants of R and D decisions				Determinants of R and D intensities			
	RDec (1)		*DDec* (2)		*RInt* (3)		*Dint* (4)	
Size	0.120***	(0.006)	0.067***	(0.007)	1.957***	(0.057)	1.777***	(0.058)
SizeSq	-0.010***	(0.001)	-0.003***	(0.001)	-0.211***	(0.006)	-0.189***	(0.006)
MarkPower	-0.025***	(0.005)	0.009	(0.006)	0.334***	(0.048)	0.309***	(0.049)
MarkPowerSq	0.002***	(0.001)	-0.001	(0.001)	-0.041***	(0.005)	-0.036***	(0.005)
DemPull	0.032*	(0.018)	0.185***	(0.020)	3.014***	(0.163)	3.546***	(0.165)
TechOpp	0.286***	(0.023)	0.011	(0.026)	3.716***	(0.197)	2.179***	(0.200)
Appr	-0.011	(0.011)	0.071***	(0.012)	1.445***	(0.108)	2.176***	(0.109)
ContR&D	0.326***	(0.004)	0.374***	(0.006)	0.699***	(0.041)	0.714***	(0.042)
Year06	0.103***	(0.004)	0.128***	(0.004)	0.151***	(0.038)	0.086**	(0.038)
Year07	0.064***	(0.004)	0.090***	(0.004)	0.197***	(0.038)	0.145***	(0.039)
Year08	0.039***	(0.004)	0.053***	(0.004)	0.186***	(0.038)	0.094**	(0.039)
Observations	17,335		17,335		5,348		5,348	

Marginal effects are reported. Standard errors in parentheses.
*significant at 10%, ** significant at 5%, *** significant at 1%.

Tests of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPower*, *MarkPowerSq*, *DemPull*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Tests of equality of estimated coefficients of *Size*, *SizeSq*, *DemPull*, *TechOpp* and *Appr* across equations (3) and (4) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Test of equality of estimated coefficients of *MarkPower* and *MarkPowerSq* across equations (3) and (4) does not allow us to reject the null hypotheses of equality of coefficients.

Table A3. Determinants of research and development intensities
Basic specification. Robustness check 2

	RInt (1)		*Dint* (2)	
Size	1.893***	(0.081)	1.748***	(0.077)
SizeSq	-0.187***	(0.009)	-0.180***	(0.009)
MarkPower	0.196***	(0.066)	0.418***	(0.062)
MarkPowerSq	-0.026***	(0.006)	-0.041***	(0.006)
DemPull	0.145	(0.129)	1.276***	(0.124)
TechOpp	0.691***	(0.170)	0.189	(0.162)
Appr	0.179**	(0.088)	0.614***	(0.085)
Year06	0.093***	(0.032)	0.190***	(0.031)
Year07	0.051	(0.032)	0.142***	(0.031)
Year08	0.082**	(0.032)	0.108***	(0.031)
Observations	8,984		8,984	

Marginal effects are reported. Standard errors in parentheses.
*significant at 10%, ** significant at 5%, *** significant at 1%.
Tests of equality of estimated coefficients of *MarkPower*, *DemPull*, *TechOpp* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 (*DemPull* and *Appr*), the 0.05 (*MarkPower*) and the 0.10 (*TechOpp*) levels. Test of equality of estimated coefficients of *Size*, *SizeSq* and *MarkPowerSq* across equations (1) and (2) does not allow us to reject the null hypotheses of equality of coefficients.

Table A4. Determinants of research and development
Two part model. Robustness check 2

	Determinants of R and D decisions				Determinants of R and D intensities			
	RDec (1)		*DDec* (2)		*RInt* (3)		*Dint* (4)	
Size	0.247***	(0.010)	0.231***	(0.010)	2.441***	(0.054)	2.216***	(0.055)
SizeSq	-0.022***	(0.001)	-0.021***	(0.001)	-0.251***	(0.005)	-0.227***	(0.006)
MarkPower	0.015*	(0.008)	0.042***	(0.008)	0.331***	(0.046)	0.387***	(0.047)
MarkPowerSq	-0.002**	(0.001)	-0.004***	(0.001)	-0.042***	(0.004)	-0.044***	(0.004)
DemPull	0.001	(0.017)	0.123***	(0.016)	1.700***	(0.106)	2.165***	(0.108)
TechOpp	0.048**	(0.022)	-0.010	(0.021)	1.883***	(0.139)	1.066***	(0.142)
Appr	0.011	(0.011)	0.052***	(0.011)	0.893***	(0.078)	1.283***	(0.080)
Year06	0.015***	(0.004)	0.031***	(0.004)	0.184***	(0.035)	0.115***	(0.035)
Year07	0.011***	(0.004)	0.025***	(0.004)	0.114***	(0.035)	0.062*	(0.035)
Year08	0.010**	(0.004)	0.017***	(0.004)	0.105***	(0.035)	0.042	(0.036)
Observations	8,984		8,984		3,924		3,924	

Marginal effects are reported. Standard errors in parentheses.
*significant at 10%, ** significant at 5%, *** significant at 1%.

Tests of equality of estimated coefficients of *MarkPower*, *DemPull* and *Appr* across equations (1) and (2) allow us to reject the null hypotheses of equality of coefficients at the 0.01 (*DemPull*), the 0.05 (*Appr*) and the 0.10 (*MarkPower*) levels. Test of equality of estimated coefficients of *Size*, *SizeSq*, *MarkPowerSq* and *TechOpp* across equations (1) and (2) does not allow us to reject the null hypotheses of equality of coefficients.

Tests of equality of estimated coefficients of *Size*, *SizeSq*, *DemPull*, *TechOpp* and *Appr* across equations (3) and (4) allow us to reject the null hypotheses of equality of coefficients at the 0.01 level. Test of equality of estimated coefficients of *MarkPower* and *MarkPowerSq* across equations (3) and (4) does not allow us to reject the null hypotheses of equality of coefficients.