Is corporate R&D just a matter of money? The combined effect of a firm's economic characteristics and perception of science

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This research considers a model based on the hypothesis that the propensity among firms to undertake R&D activities is linked both to their economic and structural characteristics and to variables related to their perception of science, their appraisal of the benefits and risks of investing in R&D, and their attitude toward the role science plays within the firm. To do so, it is based on the results of a survey administered to a representative sample of the universe of Spanish companies. The results obtained evidence that together with firms' economic and financial characteristics, which have traditionally been considered crucial factors for investing and engaging in R&D, firms' perception of science is also a major factor when analysing the way in which firms address these processes.

Keywords: Perception of science, economic characteristics, R&D activity, engagement in R&D, business, R&D in Spanish firms

INTRODUCTION

Scientific advances and technological change are key factors in the development and well-being of modern societies (David and Foray 2002; OECD 2004). Numerous authors have associated investment in research and development (R&D) with higher productivity, improved manufacturing technology, and better ratios for the returns on investment and innovation (D'Artis and Siliverstovs 2016; Kleinknecht and Mohnen 2002; Shefer and Frenkel 2005).

Given this need to consider a new perspective over and above the purely economic ambit, this research delves deeper into the subject of supplementing economic factors with those of a cultural and subjective nature when explaining business decisions related to R&D. Our aim is to show how the perception of science and R&D within the business sector may be incorporated as a variable within the traditional models that explain behaviours in R&D. A model is therefore proposed that considers both a firm's economic characteristics and its managers' perception of science and R&D when explaining the probability of engaging (or not) in R&D.

The study is based on the results of a survey administered to a representative sample of the universe of Spanish companies, which has allowed determining the profiles of Spanish firms' attitude and behaviour regarding R&D.

This study adopts a sociological approach that includes opinions, attitudes, motivations, and expectations in the business sector to help explain part of the gap between research and business and improve the policies for incentivising corporate R&D that are most effective for the goals considered at macroeconomic level. We specifically propose the tools used in the field of the Public Understanding of Science (PUS) (Bauer, Allum, and Miller 2007; see also Bauer and Falade 2014 for a review), with the aim being to find answers on the research behaviour of firms that go beyond their provisioning (or not) of resources.

Furthermore, this research resolves the excessive specificity of the samples used in prior studies on the business sector, which have focused on concrete sectors or which use cohorts that contain solely large corporations or highly innovative companies. This situation perpetuates the vicious circle of disinformation on the business sector and overlooks sectors that are traditionally ignored in this kind of analysis, such as services.

The following sections present a brief review of the main economic variables that have been related to the corporate decision to engage in R&D, together with a reasoned justification of the need for this analysis to include variables reflecting firms' perception of science and R&D. We present a series of hypotheses based on the prior literature review and on the state-of-the-art, followed by a discussion of our methodological approach. The research's main findings are then presented, going on to conclude with the discussion of their significance and implications for business and policymaking in R&D and innovation, and the study's main conclusions.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

The influence of firms' economic characteristics on their engagement in R&D

A firm's size, the resources available to it, and its ability to generate economic resources are variables that appear in most of the studies designed to understand firms' engagement in R&D. Among these, perhaps firm size is the one that has received the most attention and the one most widely debated. Numerous studies have reported that a larger size may have a series of advantages or intangible effects that may impact upon the corporate decision to invest and engage in R&D activities, as well as upon research performance. Large firms would thus have more resources to invest and engage in R&D, furthermore leading to greater returns in a kind of virtuous circle that would be difficult for smaller ones to access, in which R&D generates returns and growth, and these in turn foster R&D (Blanes and Busom 2004; Wang

2010).

Nevertheless, since the review compiled by Cohen, Levin, and Mowery (1987) there have been increasingly more studies that report uneven results and even contradictory ones on the relationship between size and engagement in R&D, indicating the existence of a negative relationship, a U-shaped relationship, and other non-linear relationships between scale and R&D, or even no direct relationship between the two (Di Masi and Grabowski 2012; Pammolli, Magazzini, and Riccaboni 2011; Shefer and Frenkel 2005; Symeonidis 1996; Ugur et al. 2016).

Another variable that may explain a firm's predisposition to engage in R&D is the availability of internal resources (Hall 2002). Studies such as those by Shefer and Frenkel (2005) single out revenue as one of the main variables explaining firms' R&D expenditures. The decision to invest would be influenced by the greater or lesser ease of affording the investment and implementing and commissioning the infrastructure required for engaging in R&D activities (Baumann and Kritikos 2016; Hall 2002). Elsewhere, a direct relationship has also been found between the capability for funding R&D – and doing so in a sustained and successful manner over time, on the one hand – and successful R&D on the other (Baumann and Kritikos 2016; García-Quevedo, Pellegrino, and Vivarelli 2014). From this perspective, a predisposition to invest in R&D would be determined not so much by the availability of resources in absolute terms, considered as surplus, but instead by the firm's ability to generate them efficiently and so guarantee a continuous investment. Along these lines, studies such as those by Hundley, Jacobson, and Park (1996) and Bah and Dumontier (2001) have revealed that, among other financial variables, profitability is related to intensity in R&D. Profitable firms, with suitable margin levels and with substantial asset returns would provide the right economic conditions for favourably conditioning the decisions on investing in R&D.

Finally, having the necessary resources available for the investment often involves considering the firm's capability for negotiating outside borrowing (Hall et al. 2016). This means firms that increase their leverage may be forced to reduce their R&D intensities (Baumann and Kritikos 2016), and levels of borrowing may pose a handicap for R&D activities because of the lack of trust among creditors (Holthausen and Leftwich 1983; O'Brien 2003). In this sense, Hall (1992) reported that R&D intensive firms have relatively less debt in their capital structure than those firms that are less intensive and, based on an extensive review of the prior literature, she later stated (Hall 2002, 181) that 'debt is a disfavoured source of finance for R&D investment'. Baumann and Kritikos (2016) contend that micro firms may suffer more from limited access to capital markets and outside borrowing, while authors such as Acs, Audretsch, and Feldman (1991) found that smaller firms with more debt actually increased their R&D effort. In a study of Spanish firms, Galende del Canto and Suárez Gonzalez (1999) did not find any relationships between high levels of debt or leverage and the inhibition of R&D activities, whereas assets are indeed a significant variable.

In the light of what has been stated here regarding how firms' structural and economic characteristics may be related with their decisions on investing and engaging in R&D, the following hypotheses are now formulated:

H1: Firm size is directly related to the propensity among firms to engage in R&D.

H2: The obtaining of profits is directly related to the propensity among firms to engage in R&D.

H3: The capability to generate resources is directly related to the propensity among firms to engage in R&D.

H4: A firm's level of debt is directly related to the propensity to engage in R&D up to a certain degree, after which it becomes a handicap.

Perception of science and research performance in firms

Different studies have pointed out that the attitude towards R&D and innovation and certain cultural aspects are related to efforts in R&D and to innovation outcomes. In recent years, when explaining firms' behaviour in relation to R&D and innovation, greater importance has been given to extra-economic factors, such as skills, qualifications and competencies, habits and routines, human capital, culture, internal and external networks, and tacit knowledge (Galende del Canto and Suárez Gonzalez 1999; Kaasa 2013; McEvily and Chakravarthy 2002; Varsakelis 2001).

Scientific culture comprises different dimensions: epistemic (knowledge), attitudinal or evaluative (beliefs and attitudes), and behavioural (what individuals do with what they know, and with their beliefs and attitudes) (Cámara Hurtado and López Cerezo 2012). In a previous paper (Rey-Rocha, Muñoz-van den Eynde, and López-Navarro 2019) we put forward the concept of scientific culture and its different dimensions applied to the business sector, and introduced our approach to understand the image of science in the business sector by investigating the factors that shape this image and ultimately the role they play in the development of a culture of science and innovation within companies. Scientific culture is a specific characteristic of each firm, and although it may be more or less assimilated by the workforce as a whole, it is firmly 'guided' by the perception of those individuals that make the decisions. People located in these positions seek to achieve corporate goals, even personal successes, yet their behaviour cannot be understood solely as that of a rational being that exploits its resources to the full -as they were portrayed in neoclassical economics-. In the field of economic sociology, Zelizer (2010) notes that economic action has a strong social embeddedness. Behind the supposedly impersonal worlds of production, consumerism, and the conveyance of goods there are people that make decisions guided also by cultural and social factors, such as their perception of science.

As Kenney and Goe (2004, 692) suggested ‘economic action is also influenced by the web of social relationships and institutions in which the individual or organization is embedded’. These people are rooted in complex social macrostructures –in which they observe certain values and beliefs related to risk, progress or knowledge- as well as in the very culture of their sector and, finally, in that of their own company. This cultural and regulatory system –whether at macro or micro level -fosters certain attitudes toward R&D and discards or even penalises others. As we have already noted ((Rey- Rocha and López-Navarro 2016) ‘our approach assumes that the relationship of businesses with science, R&D and innovation depends on and simultaneously determines the image the business sector holds about these concepts’. This lead us to postulate that ‘both entrepreneurs and business managers shape an image of science, R&D and innovation as a result of their interaction with them in their daily professional life within a specific social environment’, and simultaneously, ‘their social environment influences this image as a result of the relationship between business, on one hand, and science and scientific knowledge, on the other hand’.

Nevertheless, it is rare to come across studies in economics and management that enter into a dialogue with other areas in the social sciences in search of answers to the way firms behave in relation to R&D. There are, nonetheless, certain exceptions, such as the studies by Varsakelis (2001) that related national culture to R&D activities, or those by Taylor and Wilson (2012) in which they contended that simply investing in R&D or in a firm’s infrastructure need not necessarily have a direct impact on innovation if there is not a culture of innovation or certain specific values of that culture with a bearing on those decisions.

The sole approach so far made in Spain with empirical data is that by López-Navarro, Garzón-García, and Rey-Rocha (2011) based on the Survey on the Social Perception of Science and Technology organised by the Spanish Foundation for Science and Technology

(Fundación Española para la Ciencia y la Tecnología, FECYT). The authors singled out a subgroup from the overall sample that consisted of entrepreneurs and self-employed workers, in which they detected attitudes and expectations that differed from the rest of the population in matters related to institutional trust –specifically toward public research bodies– and the management of risk posed by science and technology. Although the study had a series of limitations arising from a questionnaire designed to measure the general perception of science among the population at large, the results provided certain keys for beginning to understand the distance between the private sector and the institutions responsible for generating scientific knowledge.

The approach from the perspectives of PUS and public perception of science permits addressing the issue of engagement in R&D from a broader perspective integrating matters related to attitudes toward S&T within the firm related to the control of the research process, trust in researchers, research-related expectations, and the role of scientific knowledge in firms. This discipline works with such variables as the attitude or interest toward science, science's social image, and the perception of the risks and benefits for seeking to understand people's predisposition to adopt a pro-scientific stance (Allum et al. 2008; Bauer 2009; Cámara, Muñoz van den Eynde, and López Cerezo 2018).

Based on the above reasoning, we may assume that the image and perception of science may be related with the decision that a firm's managers make on whether or not to engage in R&D activities. More specifically, the following hypotheses are formulated:

H5: The way firms perceive science is directly related to their propensity to engage in R&D.

H5a: A positive perception of science is directly related to a greater propensity to engage in R&D processes.

H5b: A negative perception of science is directly related to a lesser propensity to engage in R&D processes.

H6: A firm's appraisal of the benefits and risks of investing in R&D is directly related to its decisions on engaging in R&D.

H6a: An appraisal that focuses more on the benefits of investing in R&D is related to a greater propensity to engage in R&D activities.

H6b: An appraisal that focuses more on the risks of investing in R&D is related to a lesser propensity to engage in R&D activities.

H7: The corporate attitude toward the role science plays in firms is directly related to the decisions to engage in R&D.

MATERIAL AND METHODS

Population and sample

The questionnaire 'Scientific culture, perception and attitudes toward science and innovation in the Spanish business sector' -shortened to Scientific Culture at Enterprises, SCe; in Spanish Cultura Científica Empresarial, CCe- (Rey- Rocha and López-Navarro 2016), designed specifically for this research, seeks to elicit the opinions, attitudes, motivations, expectations and images that the Spanish business sector has regarding science, R&D and innovation.

The questionnaire was administered by telephone in 2016 to informants consisting of people with managerial responsibilities in a sample of 707 companies representative of the universe of Spanish companies. The reference population involved the number of active firms with full economic data as of December 2014 in the Iberian Balance sheet Analysis System (SABI database, Sistema de Análisis de Balances Ibéricos in Spanish). Out of the total number of Spanish firms in the population that met those characteristics (451,181) a

representative sample was obtained, stratified by size (number of employees) and activity sector. The final sample size after the telephone surveys was $n=707$ companies, with an error of $\pm 3.7\%$, for a 95% confidence level (1.96σ with respect to μ , for $p=q=0.5$). A detailed description of the population and sample, as well as further methodological details, were published previously (Rey-Rocha, Muñoz-van den Eynde, and López-Navarro 2019).

Model and variables

According to the hypotheses formulated here, a model is presented in which engagement in R&D activities is informed by a series of variables of an economic nature and involving the perception of science and R&D (Figure 1).

Figure 1. Model

Table 1 contains the variables used in the study, including their description and the expected relationship with the explained variable according to the hypotheses formulated, which are reflected in the model proposed.

Table 1. Variables included in the study

Variables			Hypothesis and expected relationship
Explained variables: Engagement in R&D			
R&D R&D_i R&D_e R&D_c	Engagement in R&D activities Intramural R&D Extramural R&D Collaborative R&D	1: if the firm has engaged in some form of R&D 0: otherwise	
Explanatory Variables: Economic variables			
Size			
SIZE_ECO	Cluster by Sales and Total Assets	1 Micro enterprise 2 Small enterprise 3 Medium enterprise 4 Large enterprise	H1: +
Resources			
EBIT	Earnings before interest and tax	Ordinal 1 to 5 (quintiles)	H2: +
NI	Net income	Ordinal 1 to 5 (quintiles)	
Resources capability			
ROA	Return on assets (EBIT/NI)	Ordinal 1 to 5 (quintiles)	H3: +
ROE	Return on equity (NI/Equity)	Ordinal 1 to 5 (quintiles)	
PM	Profit margin (EBIT/Sales)	Ordinal 1 to 5 (quintiles)	
AT	Asset turnover (SALES/Total assets)		
Leverage			
LEV	Leverage	Ordinal 1 to 10 (deciles)	H4: +/-
Explanatory variables: Perception variables			
Ideas and values associated with science			
PPI	Positive Perception Index	Positive perception of science	H5a : +
NPI	Negative Perception Index	Negative perception of science	H5b: -
Motivation to engage in R&D activities			
MOEI	Motivation to Engage Index	Benefits for firms of investing in R&D	H6a: +
MIEI	Mitigation of Engagement Index	Risks for firms of investing in R&D	H6b: -
Attitudes			
TRST	Trust	Trust in scientists	H7: +
CONT	Control	Control of R&D and independence of researchers	
EXPT	Expectations	Expectations in science	
SKNW	Scientific knowledge	Value of scientific knowledge	

Explained variable: Engagement in R&D activities

Firm engagement in R&D activities has traditionally been measured with economic or quantitative output variables, such as patent requests, income from patents, scientific articles, and profits from new technologies or products (Kaasa 2013), or with the input type in the form of the business effort involved in R&D activities - expenditures on R&D in absolute terms or over sales, as representing the intensity of the effort, are very common variables in the studies on firms' innovative behaviour -. Nevertheless, the amount allocated to R&D is a decision made after the firm has expressed its intention to engage in these activities and is conditioned by the availability of resources. This means the decision to spend on research in firms begins with a prior intent or decision to do so (Rosenberg 1990).

This research focuses on identifying those factors that induce a firm to engage in R&D activities. To do so, its explained variable involves the answers the entrepreneurs and company managers surveyed have provided to the question in the SCe questionnaire that asked them whether their firm had or had not engaged in R&D over the previous five years (2011-2015). This means the R&D variable is dichotomous, taking the value 1 if the firm has engaged in some form of R&D, and 0 otherwise. Considering the model caters for the possible existence of differences when deciding upon the pathway for engaging in R&D activities, three further variables are defined: R&D_i, to cover the engagement or not in intramural R&D (i.e., within the company); R&D_e, covering the acquisition of extramural R&D (i.e., carried out by other public or private organizations); and R&D_c, for covering the engagement in collaborative R&D (i.e., carried out jointly with other public or private organizations). Like the R&D variable, these ones also take values of 1 or 0.

Explanatory variables: Economic data and perception of science and R&D

Economic variables

The surveyed companies' economic data for 2014 were obtained from the SABI database. The selection has consisted of nine variables commonly used in microeconomic business studies as illustrative of a firm's economic and financial situation, being grouped into four dimensions: size, resources, resources capability, and leverage.

Firm size has been measured through two generally accepted variables, sales and total assets. To avoid the impact the variables' biased distribution has on the sample, the values used correspond to the Napierian logarithms of the original values. Given the high correlation between these two variables, they have been merged into a single ordinal categorical variable (SIZE_ECO) calculated using a k-means cluster analysis. Each one of the clusters or values of the variable SIZE_ECO has been associated with the generally accepted terminology of micro, small, medium and large enterprise (Table 2).

Table 2. Variable 'SIZE_ECO' calculated by a k-means cluster analysis (variables clustered 'sales' and 'total assets')

	Final cluster centres Cluster (SIZE_ECO)			
	1 (Micro)	2 (Small)	3 (Medium)	4 (Large)
Ln Sales (milEUR)	4.6	5.5	7.2	8.8
Ln Total assets (milEUR)	4.2	5.9	6.9	9.1
% cases assigned to cluster	27.5%	35.9%	27.9%	8.7%

The need to maintain a certain position of leadership, market share or competitive position through size may provide the incentive to engage in R&D projects. Nevertheless, they do not per se guarantee the firm will have the resources required for an activity that incurs a high investment cost. If the theory of 'I have therefore I invest in R&D' holds true, profitable firms will be more willing to engage in R&D projects, as they have a sufficient surplus to cover the cost. Hence the reason the second dimension, Resources, contains two variables associated with the measurement of a firm's results: earnings before interest and tax (EBIT) and net income (NI). The consideration of both variables permits an analysis to be made of the impact that the pressures of financial expenditure may have on the availability of resources for R&D.

To avoid the aggregate and absolute nature of the above metrics, four variables have been introduced linked to a firm's efficiency and its capability for generating income, and they are grouped into the dimension Resources capability: return on assets (ROA), return on equity (ROE), profit margin (PM) and asset turnover (AT). These last two provide information on the firm's strong points as regards its efficiency and its ability to generate income (González-Bravo and Mecaj 2011).

The instability and asymmetry in the distributions of these ratios may lead to inappropriate results and conclusions when they are included in the regression models (De Andrés 2001). For this reason, the variables EBIT, NI, ROA, ROE and PM have been typified to relativize each firm's value to the average in its sector, and then gathered into five groups (quintiles). The AT variable has an appropriate distribution, so its original formulation has been used as a continuous variable.

Finally, leverage (LEV) is an indicator that rates the capability for obtaining additional resources and the extent to which a firm may find its hands tied by a high dependence on outside capital, needing to negotiate without further compromising its

situation (Mecaj and González-Bravo 2013). In view of its asymmetric distribution, it has been classified in the intervals 1 to 10, according to its deciles, in order to fit a second-degree curve. As it is suspected that the relationship with the explained variables may not be monotonic, it has been inserted in the model as a quadratic term (square of the categorical variable) for accepting or rejecting this hypothesis.

Perception variables

Perception is the cognitive process that implies processing the scientific information from our environment and rebuilding it by means of its assimilation into our mental maps (Damasio 2010; Mather 2006). The perception of science and R&D is addressed in this study through three dimensions: a) Ideas and values associated with science, b) Motivation to engage in R&D activities, and c) Attitudes towards S&T, R&D, scientific knowledge, and scientists within companies.

The former reflects the ideas and values commonly associated with science. The positive and/or negative perception that entrepreneurs and company managers may have of science permits outlining the possible existence of basic trust toward those activities that inform scientific advancement. Accordingly, the SCe questionnaire maintains a similar approach to other questionnaires such as the Social Perception of Science and Technology Questionnaire of the Spanish Foundation for Science and Technology (FECYT 2007), and the PIKA Questionnaire on Perception, Interest, Knowledge and willingness to Act regarding science (Muñoz van den Eynde, Laspra, and Díaz 2017), which includes a question on the extent to which science is associated with different ideas. Specifically, the SCe questionnaire has chosen to adopt the same approach as PIKA, asking respondents to rate the extent to which when thinking about 'science' a series of ideas come to mind related to positive and negative factors, on an answer scale from 1 (not at all) to 5 (a lot). The answers have been

used to create two indices that express the degree of positive and negative perception, respectively, of science: PPI (Positive Perception Index), as the average of each respondent's score for the items of progress, security, usefulness, economic development and effectiveness; and NPI (Negative Perception Index), as the average of the scores for the items of boredom and mistrust.

The dimension Motivation to engage in R&D activities includes two indices that measure the extent to which engagement in R&D is motivated or mitigated in firms. Both have been built using the answers to the question on the benefits and risks for firms investing in R&D. The SCe questionnaire asked respondents to rate their degree of agreement on a scale from 1 (don't agree) to 5 (fully agree) with the following statements: a firm investing in R&D 1) makes a very risky investment with a high degree of uncertainty; 2) generates long-term economic benefits; 3) will be forced to lay off workers, as its production and service delivery processes become more efficient ; 4) will enjoy a competitive advantage; 5) improves its image in the market; 6) wastes time, as it is always more profitable to use knowledge generated by others; 7) helps to generate new jobs within the company itself; and 8) may generate risks to health and the environment.

It should be stressed that the question does not pitch the benefits/advantages of science against its risks/disadvantages, an approach that would significantly hinder the detection of the level of criticism. Therefore, as noted by Laspra (2014), not having to choose between two mutually excluding terms allows identifying tolerable benefits and risks, accepting that someone may consider science to have a high level of both benefits and risks at the same time.

The MOEI (Motivation to Engage Index) has been calculated as the average scores for the items that single out the benefits for firms of investing in R&D (items 2, 4, 5 and 7);

and MIEI (Mitigation of Engagement Index) has been calculated as the average scores for the items that single out the risks for firms of investing in R&D (items 1, 3, 6 and 8).

The third dimension covers Attitudes towards the role played within firms by science and technology, R&D, scientific knowledge, and scientists. The SCe questionnaire asks respondents to give their opinions on matters related to control and independence (specifically the need for control over R&D and researchers within companies), trust, expectations regarding S&T, and the role and relevance of scientific knowledge for decision-making within companies and their willingness to use it. In particular, respondents have to rate, on a scale from 1 (don't agree) to 5 (fully agree), their level of agreement with the following statements:

- (1) Scientists should play a more important role in business.
- (2) When a company funds an R&D project, it is better to allow researchers complete freedom, without imposing the pace of the private sector.
- (3) When a company collaborates with a research group, it can share, in absolute trust, detailed information on its internal organization.
- (4) Often we place too many expectations on what science and technology can do for our company.
- (5) When a company funds an R&D project, it is important to maintain control of the activity and to orient it toward the company's own interests.
- (6) When making decisions in the company, its values and traditions must be taken into account beyond strictly scientific knowledge.
- (7) Science and technology can solve any type of business or production problem.
- (8) In companies there is sensitive information that should not be entrusted to scientists who collaborate with them.
- (9) Scientific knowledge is the best basis for making business decisions.

The answers have been used to build four indices based on the following average scores: a) Trust (TRST), for items 1, 3 and 8; b) Control (CONT): for items 2 and 5; c) Expectations (EXPT): for items 4 and 7; and d) Use of scientific knowledge (SKNW): for items 6 and 9. Items 2, 4, 6 and 8 were recoded by reversing the scale to properly reflect the concepts of control, expectation, use of knowledge, and trust, respectively.

To explore the relationships between multiple explanatory economic and perception variables and firms' engagement in R&D, a separate logistic regression analysis has been conducted for each one of the explained variables. The coefficients obtained for those explanatory variables with suitable levels of significance estimate their relationship with engagement in R&D activities. Positive sign for the coefficients indicates that an increase in the explanatory variable is related with an increase in the likelihood of a firm performing R&D activities. This provides a profile of the firms engaging in these processes.

The statistical programme SPSS v.23 was used for the estimation.

RESULTS

Descriptive univariate statistics provided an initial view of the possible existence of differences in the economic variables and in the perception of science and R&D between firms that engage in R&D and those that do not (Table 3). The results show that firms engaging in some form of R&D, compared to those that do not, are defined by a higher asset turnover (AT), a higher economic return (ROA), and a lower level of leverage (LEV). Furthermore, their managers have a significantly higher positive perception of science (PPI) and a markedly lower negative perception (NPI). Moreover, companies involved in research are much more motivated to engage in these activities (MOEI). Nevertheless, and in terms of mitigation, the MIEI does not show significant differences between companies that engage in research and those that do not, which means the factors that tend to mitigate R&D have the

same impact on both of them. Finally, none of the variables in the attitudes dimension was statistically significant enough to differentiate between these two kinds of firms. The differences become clearer when R&D activities are analysed in greater detail, differentiating between intramural, extramural, and collaborative R&D.

A summary of the results for the models is provided in Table 4, and the detail of each analysis is shown in the Appendix.

In regression Model 1, whose explained variable (R&D) covers a firm's engagement, or not, in some form of R&D, the significant variables are firm size in economic terms (SIZE_ECO), asset turnover (AT), and the Motivation to Engage Index (MOEI). The move from category or cluster 1 to 2 in SIZE_ECO (i.e., from micro to small enterprises) is not significantly related with an increase in the likelihood of the firm in question being engaged in R&D (Sig. = 0.8). However, the move to categories 3 and 4 (medium and large enterprises) certainly is (Sig. < 0.05). As for all the other economic variables, only AT was significant, whereby the probability that a given firm is engaged in R&D activities increases in step with its capability for obtaining returns from its asset investment through sales. At the same time, the positive appraisal of R&D for the firm through the recognition of the benefits arising from investment in R&D activities (MOEI) is also linked to the probability of actually doing so. Generally speaking, therefore, those firms that can appreciate the benefits of investing in R&D and whose turnover justifies the investment made are those which engage in R&D activities, and this is the case mainly among medium and large enterprises. The model accurately classifies only a relatively small number of cases (64.6%), which is not significantly better than if they were classified at random), and Nagelkerke R² is low (0.085). Nevertheless, it does provide a guide on the variables related to the decision on engaging in R&D and in which direction.

Table 3. Differences in the explanatory variables between companies doing and not doing R&D

	R&D		R&D_i		R&D_e		R&D_c		TOTAL
	Yes	No	Yes	No	Yes	No	Yes	No	
n (%)	271 (38.3%)	436 (61.7%)	205 (29.0%)	497 (70.3%)	134 (19.0%)	569 (80.5%)	146 (20.7%)	556 (78.6%)	707 (100%)
Mean (Standard error of the mean)									
<i>Size</i>									
Sales	4043.3 (2848.6)	1090.4 (197.6)	4389.3 (3690.2)	1272.0 (332.1)	5219.2 (3446.7) (*)	1378.4 (435.3)	4613.2 (3226.0)	1434.0 (411.5)	2093.8 (744.7)
Total assets	5857.5 (4647.4)	1563.0 (1076.3)	7104.6 (6126.6)	1515.7 (936.6)	8043.2 (6681.6)	1784.2 (998.3)	8192.9 (6590.9)	1699.1 (908.2)	3046.8 (1545.5)
<i>Resources</i>									
EBIT	283.7 (252.8)	-13.0 (25.5)	301.4 (331.8)	14.7 (25.8)	450.8 (398.3) (*)	17.6 (46.3)	329.7 (402.4)	37.4 (33.9)	98.1 (87.6)
NI	132.5 (207.0)	-33.5 (22.8)	124.7 (272.2)	-10.0 (22.2)	199.4 (335.3)	-6.6 (36.5)	183.5 (344.3)	-9.2 (25.7)	31.0 (74.5)
<i>Resources capability</i>									
ROA	.05 (.01) (*)	.001 (.01)	.04 (.01) (*)	.01 (.01)	.08 (.01) (*)	.01 (.01)	.08 (.01) (*)	.01 (.01)	.02 (.01)
ROE	-.07 (.11)	.18 (.06) (*)	-.14 (.14)	.18 (.05) (*)	.07 (.14)	.09 (.06)	.07 (.13)	.09 (.06)	.09 (.05)
PM	-.29 (.74)	-.23 (.11)	-.40 (.98)	-.20 (.10)	-.52 (1.5)	-.19 (.09)	-.48 (1.4)	-.20 (.09)	-.26 (.29)
AT	1.7 (.08) (*)	1.5 (.06)	1.6 (.09)	1.6 (.06)	1.9 (.13)	1.5 (.05)	1.7 (.11)	1.5 (.06)	1.6 (.05)
<i>Leverage</i>									
LEV	61.7 (1.9)	75.3 (4.6) (*)	60.5 (1.9)	74.2 (4.1) (*)	64.1 (2.9)	71.6 (3.6)	61.6 (2.8)	72.5 (3.6)	70.2 (2.9)
<i>Ideas and values associated with science</i>									
PPI	4.2 (.04) (*)	4.1 (.04)	4.2 (.05)	4.1 (.03)	4.1 (.06)	4.2 (.03)	4.2 (.06)	4.1 (.03)	4.2 (.03)
NPI	2.0 (.05)	2.1 (.05) (*)	1.8 (.06)	2.1 (.04) (*)	2.0 (.08)	2.1 (.04)	1.9 (.07)	2.1 (.04) (*)	2.0 (.04)
<i>Motivation to engage in R&D activities</i>									
MOEI	4.2 (.03) (*)	4.1 (.03)	4.2 (.04)	4.1 (.03)	4.2 (.05) (*)	4.1 (.03)	4.2 (.05)	4.1 (.03)	4.1 (.02)
MIEI	2.2 (.04)	2.2 (.03)	2.1 (.04)	2.2 (.03) (*)	2.1 (.05)	2.2 (.03) (*)	2.1 (.05)	2.2 (.03)	2.2 (.02)
<i>Attitudes</i>									
TRST	3.6 (.05)	3.6 (.03)	3.6 (.05)	3.6 (.03)	3.6 (.06)	3.7 (.03)	3.6 (.06)	3.7 (.03)	3.6 (.03)
CONT	3.1 (.06)	3.0 (.04)	3.2 (.07) (*)	3.0 (.03)	3.1 (.09)	3.0 (.03)	3.0 (.06)	3.0 (.04)	3.0 (.03)
EXPT	2.8 (.05)	2.8 (.04)	2.8 (.06)	2.8 (.03)	2.8 (.07)	2.8 (.03)	2.7 (.06)	2.8 (.03)	2.8 (.03)
SKNW	2.9 (.05)	2.9 (.04)	2.9 (.06)	2.9 (.04)	3.0 (.07) (*)	2.9 (.04)	3.0 (.06)	2.9 (.04)	2.9 (.03)

Mean values were compared with Student's t test with Bonferroni correction

(*) Significant differences are reported at $p < .05$ in the two-sided test of equality for column means, assuming equal variances.

Table 4. Results of regression analyses

	Model 1 R&D		Model 2 R&D _i		Model 3 R&D _e		Model 4 R&D _c	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.
SIZE_ECO(1) (micro, benchmark)		.000		.000		.000		.001
SIZE_ECO(2) (Small vs micro)	-.03	.88	.18	.43	.31	.29	-.05	.85
SIZE_ECO(3) (Medium vs micro)	.81	.000	.81	.001	.77	.005	.56	.03
SIZE_ECO(4) (Large vs micro)	1.38	.000	1.01	.002	1.48	.000	1.04	.002
EBIT								
NI								
ROA								
ROE								
PM							.21	.002
AT	.16	.017			.28	.000		
LEV								
LEV*LEV								
PPI								
NPI			-.37	.000			-.25	.025
MOEI	.28	.027			.34	.034		
MIEI								
TRST								
CONT			.33	.002				
EXPT								
SKNW								
R ²	.085		.095		.081		.078	
Predicted (% global)	64.6		71.0		80.4		79.2	

Model 2, which refers to the engagement in intramural R&D, confirms the significance of only two variables associated with perception, the Negative Perception Index (NPI) and control (CONT), with a negative and positive sign, respectively. Science's close association with negative aspects is linked to a lower development of intramural R&D activities. This would constitute a barrier that we could refer to as primary, whereby some firms do not even consider the possible benefits to be gained from engaging in this form of R&D. The CONT variable's positive sign shows that engaging in intramural R&D is linked to firms' perception of the need to keep control over R&D decisions and processes when they have the resources to engage in it. As was the case in the overall model, size (SIZE_ECO) is also related to engagement in intramural R&D. This again means that medium and large enterprises are much more likely to be engaged in these activities than micro ones. It should

be noted that this is also the case in all the other models, which means size is a significant variable related with all R&D processes, regardless of the way in which they are undertaken.

The result of Model 3, which models outsourcing of R&D, is an economic variable, AT, and a perception variable, MOEI, as well as the results in SIZE_ECO, which it shares with all the other models. These results are similar to those recorded for the overall model (Model 1). Respondents of those firms that report outsourcing R&D processes positively rate the benefits research has for them and record higher levels of return on their investment through sales. It might therefore be posited that firms look elsewhere for the best agents for contracting their research needs, what's more knowing they have the resources to do so.

Finally, in Model 4, whose explained variable is engagement in collaborative R&D, besides the variable SIZE_ECO, the significant variables were once again an economic one, profit margin (PM), and a perception one, NPI. The most profitable firms are also the ones most heavily engaged in collaborative R&D. Furthermore, negative perception of science goes hand in hand with low collaboration, recording similar results to the model that seeks to explain intramural R&D. Nevertheless, in contrast to that model, in which no economic variable was significant, collaboration is considered an option when firms also have the necessary resources to be allocated to extramural R&D processes, perhaps because these resources convey an image of profitability that makes it easier to find partners, or because turning to the market reduces the risk of losing that economic advantage.

Overall, the results clearly show that firms' engagement in R&D is related to both economic and perception variables, although the extent to which they choose one or other pathway for engagement is ultimately linked to different factors. Hypothesis H1 is confirmed, whereby size is a factor that is linked to firm's propensity to engage in R&D. In turn, H3 is partially confirmed, which means a firm's capability for generating resources (specifically its turnover and margin indices) and its propensity to engage in R&D activities are directly

related. This is confirmed in the models in which engagement in R&D is in some way undertaken extramurally –either through the external acquisition of R&D or in collaboration with outside agents- and therefore in the model that encompasses the sum of R&D activities, although it does not seem to particularly affect engagement in intramural R&D. By contrast, none of the remaining variables linked to the generation of resources (return on assets and return on equity) or leverage were significant, so H2 and H4 cannot be confirmed.

H5 is also confirmed, albeit solely regarding the negative perception of science (H5b), and only regarding the R&D in which the firm is directly involved (not outsourced), whether alone or in collaboration (models 2 and 4). This means the propensity to engage directly in R&D, whether on an intramural basis or in collaboration, decreases in those firms whose managers have a more negative perception of science.

H6 is partially confirmed when the decision is to outsource R&D (model 3). Thus, the probability that firms will engage in R&D activities, in particular outsourcing those activities to outside agents, increases as entrepreneurs and company managers become aware of the benefits this decision might have for their firm.

Finally, H7 is confirmed solely for the variable that measures the control of scientists and R&D projects (CONT) in the model affecting intramural R&D, so firms seeking to exert greater control over their projects is related with R&D being undertaken internally.

DISCUSSION

Firm size is clearly related with engagement in R&D, regardless of the way in which it is conducted, intramurally, extramurally, or in collaboration. Medium and large enterprises, as opposed to micro ones, are more prone to engage in R&D activities. The non-linear nature of the relationship between size and engagement in R&D has already been reported by authors such as Symeonidis (1996), stressing that the greater propensity for R&D processes

associated with firm size always involves sufficiently large firms.

The fact that none of the other economic variables has proven to be significant on a general basis would enable us to consider whether business engagement in R&D is not so much a matter of the resources available as of another series of aspects linked to size. None of the variables indicative of the capability for generating economic results (e.g., earnings before interest and tax and net income), as well as of those strictly linked to return (on assets and on equity), are related to engagement in R&D in any of the models. This is the case, nonetheless, of the measures that reflect efficiency, profit margin and asset turnover, in which sales is one of the components of those ratios. It may therefore be contended that size is related to engagement in R&D, not because size conditions the results and resources for the investment, but instead because larger firms are more focused on maintaining their competitive advantage or leadership positioning in the market, and it is in this strategy where the benefits of R&D are considered an option. It may therefore be noted that the positive relationship between size and research always occurs within the segment of medium-large enterprises.

The relationship between firm size and engagement in intramural R&D is consistent with the stance taken by authors such as Bayona, García-Marco, and Huerta (2001), who contend that a minimum size is required to address R&D activities. Large firms therefore tend to adapt the complexity of their structure to their goals and strategy, whereby they are much more likely to internalise their R&D and organise their own departments accordingly, as is only to be expected. Their large size thus provides them with a suitable bedrock of financial, technical and human resources. Likewise, a certain size provides firms with the right image and reputation to render them appealing in R&D collaboration processes involving other organisations and agents. The higher propensity to collaborate in conjunction with size evidenced in the results is consistent with positions such as those adopted by

Bayona et al. (2001), Castro and Fernández de Lucio (2006) and Cohen and Levinthal (1989). Size therefore provides internal capabilities for R&D, associated with technological complexity and resources, which means processes may be undertaken in collaboration, accessing extramural R&D knowledge, once the processes have been interiorised and there is enough capability to generate resources.

The results have confirmed that decisions on investing in R&D are related with both the capability for actually undertaking the processes and with the propensity toward them. The economic variables/perception variables binomial is consistent with the thesis, based on the approach to innovation adopted by Quintanilla (2004), whereby the propensity to engage in R&D is related both to a firm's capability to do so and to its attitude toward science and R&D. The innovation capability, according to Quintanilla, involves not only tangible technological investment but also a culture of innovation. In turn, the propensity to innovate would include values and attitudes such as trust in science and technology. Bearing in mind the results obtained, this same approach may be applied to corporate R&D, whereby a firm's engagement in R&D is linked to its actual capability for doing so and to its propensity to do so. Together with the capability to engage in or contract R&D activities, related to firm size and certain capabilities for generating resources, the propensity to undertake R&D processes would be directly linked to the following:

- A positive perception of the benefits stemming from the investment in R&D that motivates engagement, as it is considered that such investment generates long-term economic benefits, gives the company a competitive advantage, improves its market image, and helps to generate new jobs within it.
- The absence of a negative image of science as something boring and not to be trusted.

It is important to stress this last aspect, as it may be seen as a major barrier when seeking to incentivise business entrepreneurship in R&D. The inverse relationship between a negative perception of science and engagement in R&D evidences a certain inherent rejection among firms that do not conduct research, either to engage in intramural R&D or to collaborate. It is not a problem of appraising the processes per se, but instead the appraisal of science itself and the trust held in it. We might therefore be dealing with a lack of scientific culture.

So, too, of interest are the results obtained on the effect of business attitude toward scientists, their work, and scientific knowledge. The fact that a positive attitude toward the supervision of processes is directly related to the option of directly engaging in intramural research is consistent with a sense of vulnerability or the loss of operating capacity and the risk of relinquishing control over results. Firms engaging in intramural R&D are wary of a possible loss if they share the processes with outside agents, and this seems to be a cost that restricts collaboration and outsourcing. It is not a financial matter, but instead a perceptive barrier that makes firms reluctant to share with outsiders what they consider to be key information or resources.

Those firms most prone to outsourcing perceive and value more the long-term benefits R&D has to offer them –economic benefits, competitive advantage, image, and job creation- and in their quest to maintain these results and reinforce them they do not hesitate to turn to those agents they consider to be the ones most capable and qualified for doing so. This decision may be because they acknowledge that on their own they do not have the necessary capability to do so or because they see outsourcing as the fastest and securest way of achieving results.

Within a context in which investment in corporate R&D needs to be incentivised and in which the processes of collaboration do not appear to appeal to firms, the results obtained

are still important for considering the way of undertaking possible potential initiatives. If a negative perception of science by entrepreneurs and managers appears to stop Spanish firms engaging in R&D either within the firm itself or in collaboration with other agents, then there is need to bolster the culture of science within the business sector.

On the other hand, findings on the relationship between firm size and engagement in R&D indicate there is a pressing need to support micro and small enterprises and involve them in R&D activities. It does not appear to be solely a matter of size and resources, but also a combination with a series of other intangible factors that facilitate the acquisition and development of certain capabilities for engaging in R&D.

This research constitutes an initial attempt to study the relationship between the perception of science and R&D, in combination with firms' structural, economic and financial characteristics, and engagement of companies in R&D. The absence of significant correlations with variables describing economic results and the capability firms have to generate resources indicates that other economic inputs may be involved; specifically, receiving public funding for R&D, which seems to be a major item in corporate R&D investment budgets (Cruz-Castro et al. 2018; Fariñas and Fernández 2014; Rosenberg 1990; Stephan 2012). Thus, additional research will be needed to identify and characterize the effect of other influential economic and financial factors. In turn, there are important intersectoral differences with respect to R&D investment and firm productivity—firms in high-tech sectors not only invest more in R&D but also achieve more in terms of productivity gains related to research activities— and such inter-sectoral differences are also likely to exist in the perception of science and R&D. More detailed cross-sectoral analysis of data will shed light on the differences between economic sectors. Furthermore, the data in this study provide a snapshot of a single country, Spain, and so they do not accommodate the local/regional factors (and their policies) that are so decisive in R&D and innovation processes; and may

not be representative of the business sector in different countries or regions. This study should therefore be replicated in other populations.

On the other hand, it must be taking into account that the presented correlations do not necessarily reflect causal relationships. We must highlight that this study relies on cross-sectional data collected through a questionnaire and, therefore, implicitly assumes simultaneity between R&D activities performed by the company and economic and perception variables. Further work, including the use of other quantitative and qualitative methods in addition to questionnaires may yield a richer understanding of business R&D and particularly of the relationships and connections between economic, contextual and cultural factors, and firms' engagement in R&D.

To conclude, the results show that together with firms' economic and financial characteristics, which have traditionally been related with their investment and engagement in R&D, the perception of science and R&D processes are also key factors when analysing the way in which firms address these processes. There are, indeed, subjective and cultural factors, besides those issues of an economic nature, that may motivate or mitigate firms' propensity to engage in R&D.

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