Innovation in the Business Sector:
Where There's a Will There's a Way. Managers' Perception of
Science and R&D and Firms' Engagement in Innovation

Jesús Rey-Rocha^a, M. Isabel González-Bravo^{b,c}, Irene López-Navarro^{a,b,d}

^a Department of Science, Technology and Society. Spanish Council for Scientific Research (IFS-CSIC). C/ Albasanz, 26-28. 28037. Madrid. Spain.

^b Institute of Science and Technology Studies. University of Salamanca. Edificio I+D+I. Calle Espejo, nº2. 37007 Salamanca. Spain.

^c Faculty of Economics and Business. University of Salamanca. Campus Miguel de Unamuno. Edificio FES. Avda. Francisco Tomás y Valiente, s/n. 37007 Salamanca. Spain.

^d Present address: Department of Sociology and Communication. Faculty of Social Science. University of Salamanca. Campus Miguel de Unamuno. Edificio FES. Avda. Francisco Tomás y Valiente, s/n. 37007 Salamanca. Spain

Corresponding author:

Jesús Rey-Rocha.

Spanish Council for Scientific Research (IFS-CSIC)

jesus.rey@csic.es

Preprint. This is a completed version of the manuscript that has not been peer reviewed.

Abstract

This research considers the hypothesis that firms' propensity to undertake innovation activities is linked to variables related to their perception of science, their appraisal of the benefits and risks of R&D investing, and their attitude towards the role science plays within the firm, besides their economic and structural characteristics. We explore an empirical approach to studying the implications of managers' perceptions and attitudes towards science and R&D on firms' engagement in innovation. Research is based on the survey 'Scientific culture, perception and attitudes towards science and innovation in the business sector'. Results evidence that corporate innovation decisions are not just a matter of money, and confirms the combined effect of a firm's economic characteristics and perception of science on innovation engagement. Results confirm that managers' attitude towards science and R&D is related to firms' commitment to innovation, suggesting that their attitudes and behaviour in relation to science and investment in R&D should be given a more prominent role in S&T and innovation studies and in developing models of innovation in the future. This study provides some important implications for the management of innovation in the business sector. It stresses that innovation is related with managers having a perception of science and R&D that paves the way for the allocation of a firm's resources to activities oriented towards knowledge generation and innovation. The results obtained here are still important regarding the way to address possible initiatives aimed at encouraging innovation in the business sector.

Keywords: Innovation activity, engagement, science perception, economic characteristics, business

Introduction

The capacity to introduce and assimilate innovations, as well as generate them, depends largely on firms' scientific potential and their scientific culture. Nevertheless, scientific culture and values have received little attention from scholars of organizational culture and corporate innovation, who are more concerned with economic, structural, organizational, and contextual factors.

Existing literature shows that innovation in businesses is influenced by a wide range of structural, organizational, economic, contextual and market factors (Baldrige & Burnham, 1975; Damanpour & Schneider, 2006). Nevertheless, numerous authors have pointed out that decision-making processes affecting firms' engagement in innovation are not based solely on these factors. Cultural aspects intervene in innovation decisions influencing through the preferences, expectations and incentives of individuals (Kaasa, 2016; Taylor & Wilson, 2012). The consideration of cultural factors as determinants of innovative behaviours, along with economic and structural variables, has already been applied in the pioneering studies by Shane (1993), as well as in Ulijn and Weggeman (2001), Westwood and Low (2003), Tellis, Prabhu and Chandy (2009), and Kaasa and Vadi (2010). They all report that certain cultural factors affect the expectations and incentives of societies and organizations towards innovation.

Management literature has stressed the role of factors such as the culture of innovation (Van Oostrom & Fernández-Esquinas, 2017; Fernández-Esquinas, Van Oostrom & Pinto, 2017), but less attention has been given to other, more specific dimensions of organizational culture (Wang, Guidice, Tansky & Wang, 2010), such as the culture of science. Although it is well known that not all innovation is based directly on scientific research or determined by scientific and technological developments, studies on the perception of science and technology (S&T) have highlighted the role of the culture of science, and recently linked it to innovation (Quintanilla, 2005a; Bauer & Suerdem, 2016).

In the end, firms' engagement in innovation projects depends not only on their capability to innovate -that is, on tangible, material and human resources- but also on their predisposition to do so depending on the existence of certain intangible assets (Quintanilla, 2005b; Cornell University, 2015). Along these lines, Bauer (2014) considers

it convenient to combine the search for the indicators of science culture with that of a propensity to innovate and examine their relationship.

Along these lines, different authors have been calling for the need to complement the economic approach with other disciplines required for understanding the decision process involved in research and innovation, such as sociology and science policy (Gopalakrishnan & Damanpour, 1997). In this sense, the sociological approach recognises the role played by opinions, attitudes, motivations and expectations in economic behaviour (Geels, 2004; Smelser & Swedberg, 2005). Economic action has a strong social embeddedness (Zelizer, 2010) and there are people that make decisions (even economic ones) guided also by cultural and social factors, such as their perception of science.

Our aim is to provide proof of the expected joint effect on firms' innovation engagement of economic variables (the capability to act) and attitude variables (the propensity to act). This paper explores the extent to which the firms' image of science, their perception of science, and their motivation and attitude towards science and R&D are major factors when analysing firms' engagement in innovation. We aim at providing a better understanding of how scientific culture and image of science are related to firms' innovation, as well as to contribute to consolidate cultural, attitudinal and perception factors as explanatory variables of firms' engagement in innovation.

In particular, our objective is to show that firms' scientific culture and their perception of, and attitudes towards, science and R&D must be taken into account in the explanatory models of corporate commitment to innovation. Based on the assumption that the decisions to innovate are related both to the capability for conducting the processes themselves and to the propensity towards them, in this research we consider top managers' perception of, and predisposition towards, S&T and R&D, together with firm's economic and structural characteristics, when explaining the probability of engaging (or not) in innovation activities.

Our approach applies methods and tools from the fields of Social Studies of Science (SSS) and Public Understanding of Science (PUS) to the business sector, with the aim of elucidating its relationships with science, R&D and innovation, going beyond strictly economic thinking. This article contributes to consolidate the three main significant contributions of our research line on scientific culture, perception and attitudes towards

science and innovation in the business sector. First, the consideration of cultural, attitudinal and perception factors as explanatory variables of business engagement in innovation. Second, the use of a sociological approach, specifically rooted in the tools used in the fields of Science and Technology Studies (STS) and Public Understanding of Science (PUS) (Bauer, Allum & Miller, 2007; see also Bauer & Falade, 2014, for a review). And third, the selection of the sample guaranteeing the representativeness of the results, avoiding focusing on specific sectors of the economy or solely in large corporations or highly innovative companies.

The empirical analysis is based on the results of the Scientific Culture at Enterprises (SCe) survey administered to a representative sample of the universe of Spanish companies. The results evidence that together with firms' economic and financial characteristics, which have traditionally been considered crucial factors for investing and engaging in innovation, firms' perception of and attitudes towards science and R&D are also major factors when analysing the way in which they address innovation processes.

The rest of this paper is organized as follows. In the next section, we present our research hypotheses, based on a literature review and on the state-of-the-art. We then explain our methodological approach and procedure for data analysis. Finally, we provide our findings and discuss their significance and their implications for future research and practice in innovation in the business sector, and the limitations of the study.

Literature review and hypotheses

As previously argued, decision-making in companies is guided not only by their economic and structural characteristics, but also by cultural and social factors, which include the company's culture and its environment, as well as the perception, attitudes and experiences entrepreneurs and managers have of science, R&D and innovation.

Decisions such as engaging in innovation are determined to a great extent by the knowledge, values and beliefs held by decision-makers and managers (Wiersema & Bantel, 1992). In addition, these decisions are guided by cultural and social factors. In accordance with Hambrick and Mason's (1984) upper-echelons perspective, management staff can be considered as representative of firms' perception and attitudes towards science. They constitute an aggregation of individual motives and interests, and are

embedded in complex social macrostructures, as postulated by the social economy and the New Institutionalism paradigm (Powell & Colyvas, 2008; Zelizer, 2010). Within these structures certain institutional values, traits, rules, norms and needs operate (Meyer & Rowan, 1977; Hitlin & Piliavin, 2004). For instance, these actors are embedded in the cultures of their company and activity sector. This cultural and regulatory system influences (or even determines) norms and beliefs held by firms and individuals; therefore it may favour certain attitudes towards R&D and innovation, and obviate or even penalize others.

Quintanilla (2005b) contends that the rate of innovation for any social group depends not only on its capability to innovate –that is, on the availability of skills, equipment, machinery, and ultimately of the incorporated technological culture– but that there is also a need for this capability to be actually expanded with the cultural contents incorporated into those tangible resources. In other words, the rate of innovation also depends on the actual will to do so, which requires certain representations, attitudes, values and patterns of behaviour shared by the members of the group.

Bauer (2014) claims there is a growing recognition that it may be necessary to understand the attitude towards science in relation to a cultural disposition to innovate, although the relationship between the mentalities of science and the mentality of innovation remains unclear. The specific relationship between science culture and innovation has recently been investigated by Bauer et al. (2016), although they do not apply the analysis to the business sector, whereby both scenarios –business and the perception of science– have hardly been explicitly related.

Scientific culture is a specific characteristic of each firm, and is firmly ‘guided’ by the perception of those individuals that make the decisions. Behaviour of people with managerial responsibilities cannot be understood solely as that of a rational being that exploits its resources to the full –as portrayed in neoclassical economics–. The context in which an individual or organisation is embedded conditions economic action (Kenney & Goe, 2004). The values and beliefs related to risk, progress or knowledge constitute a cultural and regulatory system that fosters certain attitudes towards innovation and discards or even penalises others.

The existence of this culture in science, R&D and innovation prompts firms to make investment decisions over and above the incentive of economic benefits, bringing into

play such factors as the attitude of entrepreneurs and managers towards R&D, uncertainty, insecurity, risks associated with R&D activities, and the valuation of the costs and benefits they entail (Dobni, 2008; Yalcinkaya, 2008; Taylor et al., 2012).

From a theoretical perspective, this research is grounded on the assumption that perceptions and attitudes of entrepreneurs and company managers can influence and even determine the scientific culture of a company. At the same time, the social environment influences entrepreneurs' and managers' culture of science and innovation. Our approach assumes, in accordance with New Institutionalism postulates, that the relationship of businesses with R&D and innovation depends on and simultaneously determines the image the business sector holds about these concepts. The scientific culture, perceptions, opinions, attitudes, motivations and expectations towards science and R&D in firms are related to firms' engagement in innovation activities, and may even act as their determinant or driver.

In this regard, the attitudinal and behavioural characteristics of managers and administrators are reported to have an important role in explaining firms' innovation activity (Ekvall & Arvonen, 1991; Yukl, 1999) to the extent that, for example, Damanpour et al. (2006, p. 216) argue that top executives are perhaps "the most influential people affecting innovation and change in organizations".

Based on the above reasoning, we may assume that, in addition to firms' structural and economic characteristics, the image and perception of science may be related with the decision that firm's managers make on whether or not to engage in innovation activities. More specifically, this leads to the hypothesis (H1) that a positive perception of science is directly related to a greater propensity to engage in innovation processes, while a negative perception of science is directly related to a lesser propensity to engage in innovation processes.

On the other hand, uncertainty and the risks that must be assumed from R&D decisions can act as a deterred barrier and as an inhibitor of firms' engagement in innovation. R&D projects do not always guarantee a short-term economic success (Jaruzelski, Dehoff & Bordia, 2005), and their returns cannot be estimated with total precision since they not only depend on the uncertainty about the success of the process, but also on the unpredictable nature of the behaviour of the demand and the response of the competition (Walker & Weber, 1984; Robertson & Gatignon, 1998). Apart from the

cost of R&D activities, risks perceived by companies include other effects such as possible job destruction and associated health and environmental risks (Ziegler & Nogareda, 2009; Harrison, Jaumandreu, Mairesse & Peters, 2014).

Uncertainty and risk condition firms' perception of the effects of innovation decisions. This perception, as input in the innovation decision process, can either favour engagement decisions in innovation, or otherwise can reinforce a culture that is not particularly proactive towards investment in innovation (Hofstede, 2001; Kaasa et al., 2010; Kaasa, 2016). A higher perceived risk may therefore cause a lower commitment to innovation (Madrid-Guijarro, Garcia & Van Auken, 2009).

According to the above arguments, the perception of the risks and benefits of R&D can become either a motivation or a deterrent for innovation investment decisions. This leads to the hypothesis (H2) that a firm's appraisal of the benefits and risks of investing in R&D is directly related to its decisions on engaging in innovation. More specifically, an appraisal that focuses more on the benefits of investing in R&D is directly related to a greater propensity to engage in innovation (H2.a); and an appraisal that focuses more on the risks of investing in R&D is directly related to a lesser propensity to engage in innovation (H2.b).

Across our research line, the approach from the STS and PUS perspectives permits addressing the issue of innovation from a broader perspective, integrating matters related to values and beliefs, interest, perceptions, and attitudes towards 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, which are ultimately related to innovation processes (Bauer, 2009).

Innovation-related processes need an 'innovative culture' (Quintanilla, 2005b; Taylor et al., 2012). The cultural characteristics at workplace that can drive processes related to innovation includes elements that may or may not favour innovation, such as the attitude towards change, the commitment to individual initiatives, the understanding and behaviour regarding risks and opportunities, the level of control in the organization, the formalization and standardization of work, the existence of norms, the development of individual creativity, the cooperativism or the support in the past for decision-making (Kaasa et al., 2010; Busse, 2014). Additionally, control, centralization in decisions and greater formalization, on the one hand, versus individual freedom, greater openness to

change, greater long-term vision, or a more communicative environment and a propensity to share information, may either inhibits or positively influence innovation decisions (Damanpour, 1991; Kaasa et al., 2010; Kaasa, 2016).

The above arguments inform our final hypothesis (H3): The propensity to engage in innovation is directly related to the corporate attitude towards the role science plays in firms, particularly to trust in scientists, agreement on the need for control over R&D and researchers, positive expectations on S&T potential, and a positive perception of the role and relevance of scientific knowledge for corporate decision-making.

Material and methods

Research instrument, population and sample

The study's results have been provided by the survey '*Scientific culture, perception and attitudes towards science and innovation in the business sector*' (Rey-Rocha & López-Navarro, 2016).

The questionnaire 'Scientific culture, perception and attitudes towards science and innovation in the business sector'—shortened to Scientific Culture at Enterprises, SCe—, is the first research tool specifically designed to investigate science perception in the business sector. It seeks to elicit the opinions, attitudes, motivations, expectations and images that the Spanish business sector has regarding science, R&D and innovation. It was administered by computer-aided telephone interviews to managers of a representative sample of Spanish companies, stratified by size (number of employees) and activity sector from the total number of active Spanish firms with full economic data in the Iberian Balance Sheet Analysis System (SABI database, Sistema de Análisis de Balances Ibéricos in Spanish).

The original population consisted on 451,181 active Spanish firms with full economic, activity sector, number of employees, turnover and contact telephone data, in SABI. Based on the structure of this population by sector and size, cluster sampling was used with a fixed number of 20 companies per cell (sector per size) and distribution of the remaining sample by simple affixation to the sector. Sample size within each sector was determined by affixation proportional to the weight of each company size, for a sample size of 700 cases. The final sample size after the telephone surveys was $n = 707$

companies, with an error of $\pm 3.7\%$, for a 95% confidence level. To match the internal representativeness of the sample to the actual distribution of the universe, prior to data processing the proportion of each cell was weighted to determine its true proportional weight based on the SABI distribution of the population. The distribution of the original population and the final sample by activity sector and company size are shown in Table 1.

Table 1: Population and distribution of the final sample by company size and activity sector.

Population						
Sector	Size (Number of employees)				Total number of companies	
	Micro <10	Small 10-49	Medium 50-249	Large ≥250		
Agriculture (primary sector)	11,985	2,962	331	48	15,326	
Industry	39,330	16,010	3,074	579	58,993	
Energy	2,331	652	185	93	3,261	
Construction	51,998	7,738	690	120	60,546	
Services	255,485	48,465	7,445	1,660	313,055	
Total number of companies	361,129	75,827	11,725	2,500	451,181	
Sample						
	Micro <10	Small 10-49	Medium 50-249	Large ≥250	Total number of companies	Margin of error
Agriculture (primary sector)	36	24	20	20	100	$\pm 9.8\%$
Industry	100	53	27	22	202	$\pm 6.9\%$
Energy	34	24	21	22	101	$\pm 9.6\%$
Construction	37	24	20	20	101	$\pm 9.7\%$
Services	118	40	23	22	203	$\pm 6.9\%$
Total number of companies	325	165	111	106	707	$\pm 3.7\%$
Margin of error	$\pm 5.4\%$	$\pm 7.7\%$	$\pm 9.2\%$	$\pm 9.4\%$	$\pm 3.7\%$	
Weighted sample						
Sector	Size (Number of employees)				Total	
	Micro <10	Small 10-49	Medium 50-249	Large ≥250		
Agriculture (primary sector)	18.8	4.6	0.5	0.1	24.0	
Industry	61.6	25.1	4.8	0.9	92.4	
Energy	3.7	1.0	0.3	0.1	5.1	
Construction	81.5	12.1	1.1	0.2	94.9	
Services	400.3	75.9	11.7	2.6	490.6	
Total	565.9	118.8	18.4	3.9	707	

Table 2. Variables included in the study

Explained variables: Engagement in R&D		
Variable	Survey question and variable definition	Descriptive statistics % or Mean(Std. dev.)
Innovation	Q17. <i>In the last 5 years (2011-2015), has your company carried out any of the following activities?</i> Q17.4. Innovation (In products, processes, organizational methods, etc.)	1 We have done this: 55.1% 0 Otherwise :44.9%
Explanatory variables: Perception variables		
<i>Ideas and values associated with science</i>		
	Q6. <i>When you think of 'science' to what extent do these ideas come to mind?</i>	
Positive Perception Index (PPI)	Average Q6.1 (Progress), 4 (Security), 5 (Usefulness), 7 (Economic development), 8 (Effectiveness)	4.2(.03)
Negative Perception Index (NPI)	Average Q6.6 (Boredom), 10 (Mistrust)	2.0(.04)
<i>Willingness to engage in R&D activities</i>		
	Q15. <i>Studies done in different countries have identified different benefits and risks of research and development or R&D for businesses. In this connection, could you tell us to what extent you agree with the following statements?:</i> <i>A company that invests in research and development or R&D...</i> 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, since it is always more profitable to use knowledge generated by others 7.Helps to generate new jobs within the company itself 8.May generate risks for health and the environment	
Motivation to Engage Index (MOEI)	Benefits for firms of investing in R&D (Average Q15.2. Q15.4. Q15.5. Q15.7)	4.1(.02)
Mitigation of Engagement Index (MIEI)	Risks for firms of investing in R&D (Average Q15.1. Q15.3. Q15.6. Q15.8)	2.2(.02)
<i>Attitudes</i>		
	Q11. <i>Now I'm going to read a series of statements. I would like you to tell me to what extent you agree with each of them.</i> 1.Scientists should play a more important role in business 2.When a company funds a research and development or 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 decisions 4.Often we place too many expectations on what science and technology can do for our company 5.When a company funds a research and development or R&D project, it is important to maintain control of the activity and to orient it towards 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	
TRUST in scientists	Average Q11.1, 3, 8 (*)	3.6(.03)
CONTROL over R&D and researchers within companies	Average Q11.2, 5 (*)	3.0(.03)
EXPECTATIONS in science	Average Q11.4, 7 (*)	2.8(.03)
Value of SCIENTIFIC KNOWLEDGE	Average Q11.6, 9 (*)	2.9(.03)
(*) Items Q11.2, 4, 6 and 8 were recoded by reversing the scale to properly reflect the concepts of control, expectation, use of knowledge and trust, respectively.		
Explanatory variables: Economic variables		
<i>To avoid the impact the economic variables' biased distribution has on the sample, these variables have been transformed and typified as shown hereafter</i>		
<i>Size</i>		
Size, in economic terms (SIZE_ECO)	Calculated by a k-means cluster analysis by 'Sales' and 'Total Assets' (natural logarithms of the original variables)	Cluster 1 Micro enterprise: 27.5% Cluster2 Small enterprise: 35.9% Cluster 3 Medium enterprise: 27.9% Cluster 4 Large enterprise: 8.7% Mean(Std. dev.)
Sales (KEUR)		2093.8(744.7)
Total assets (KEUR)		3046.8(1545.5)
<i>Resources capability</i>		
Return on assets (ROA)	Earnings before interest and tax (EBIT)/Total Assets	.02(.01)
zROA	Typified by sector. Ordinal 1 to 5 (quintiles)	
Return on equity (ROE)	Net income (NI)/Equity	.09(.05)
zROE	Typified by sector. Ordinal 1 to 5 (quintiles)	
Profit margin (PM)	EBIT/Sales	-.26(.29)
zPM	Typified by sector. Ordinal 1 to 5 (quintiles)	
Asset turnover (AT)	Sales/Total assets	1.6(.05)
<i>Leverage</i>		
Leverage (LEV)	KEUR	70.2(2.9)
zLEV	Typified by sector. Ordinal 1 to 10 (deciles)	
zLEV*zLEV	The relationship between leverage and the dependent variable fits a nonlinear, U-shaped relationship. The introduction of a quadratic term (LEV*LEV) controls this effect transforming the relationship into a second-degree curve.	
Control variables		
Firm age	Years since its foundation	18.7(10.8)
Sector	Dummies based on the sector aggregation of the CNAE (the Spanish acronym for Spain's National Classification of Economic Activities) classification of 44 sectors	Agriculture: 3.4%; Industry: 13.1%; Energy: .7%; Construction: 13.4%; Services: 69.4%

Variables

The variables used in this study have been constructed from selected survey questions which are displayed in Table 2, together with basic descriptive statistics.

Explained variable

The explained variable, '*innovation*', involves the answers the entrepreneurs and company managers surveyed have given to the question that asked them whether their firm had or had not carried out innovation activities on an ongoing basis (over the past five years).

Many studies on barriers to innovation have excluded firms that are not interested in these activities, and concentrate upon the so-called relevant samples (Coad, Pellegrino & Savona, 2016), filtering out non-innovation oriented enterprises (Pellegrino & Savona 2013). This exclusion is justified by these firms' unlikely aspiration to innovate (D'Este et al., 2012). However, our attention here focuses on evidencing the possible existence of attitudinal and motivational factors that may hamper the decision to engage in innovation activities in a prior stage, so we deem it necessary to consider both companies that do and do not engage in innovation.

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

We propose that economic and structural characteristics of firms would have a positive moderation effects. In this research, the surveyed companies' economic data include seven variables commonly used in microeconomic business studies as illustrative of a firm's economic and financial situation, being grouped into three dimensions: *size*, *resources capability*, and *leverage*. The surveyed companies' economic data were obtained from the SABI database

Firm size has been measured through two generally accepted variables, sales and total assets, representing size from the perspective of economic capacity. To avoid the impact the variables' biased distribution has on the sample, the values used correspond to the natural 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 3).

Table 3. Variable ‘SIZE_ECO’ calculated by a k-means cluster analysis
(variables clustered ‘Ln Sales’ and ‘Ln Total Assets’)

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

With a view to considering profitability as an indicator of resource availability, we have included variables linked to a firm’s capability for generating income. This second dimension, resources capability, includes: return on assets (ROA), return on equity (ROE), profit margin (PM), and asset turnover (AT). The first three are associated with the accounting measures of internal resources generated by a company: earnings before interest and tax (EBIT) and net income (NI). Moreover, PM and AT provide information on the firm’s strong points as regards its efficiency and its ability to generate income.

The variables ROA, ROE and PM record a distribution with a thick right tail. Asymmetry in the distribution of financial and accounting data may lead to inappropriate results and conclusions when they are included in the regression models (So, 1987). Ordinal variables have been created to resolve this asymmetry, with five categories based on the quintiles of the original variable. Before gathering the different sectors into quintiles, variables have been typified to relativize each firm’s value to the average in its sector and avoid the size effect.

The AT variable has an appropriate distribution, so its original formulation has been used as a continuous variable

Finally, a third dimension, leverage, 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. Leverage (LEV) also has an asymmetric distribution with a thick right tail, so it has been typified by sectors and later classified in the intervals 1 to 10, according to its deciles. The relationship between this variable and the dependent variables fits a nonlinear, U-shaped relationship. The introduction of a quadratic term (LEV*LEV) has been chosen to control this effect, thus transforming the relationship into a second-degree curve.

Perception variables

The perception of science and R&D is addressed in this study through three dimensions: a) Ideas and values associated with science, b) Willingness to engage in R&D activities, and c) Attitudes towards S&T, R&D, scientific knowledge, and scientists within companies. These three dimensions are associated with hypotheses H1, H2 and H3, respectively. Variables in these dimensions have been constructed as indices built from answers to survey questions, as stated in Table 2.

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. Perception is measured through the degree of association of science with different ideas (Muñoz van den Eynde, Laspra & Díaz García, 2017). Two indices have been created that express the degree of positive and negative perception, respectively, of science: the Positive Perception Index (PPI), as the average of each respondent's score for the items indicating science's association with positive views of progress, security, usefulness, economic development, and effectiveness; and the Negative Perception Index (NPI), as the average of the scores for the items on the negative views of science associated with boredom and mistrust.

The dimension Willingness to engage in R&D refers to another classical measurement in the PUS field: the assessment of risks and benefits (see, for example, Castell, Charlton, Clemence, Pettigrew, Pope, Quigley, Navin Shah & Silman, 2014; and European Commission, 2010). Questionnaire items have been adapted in this research to refer to the benefits and risks particularly related to the R&D process. The selection of topics has been based on a review of previous literature on R&D and innovation activities and their implications for firms in order to ensure that the items were relevant (see, for

example, European Commission, 2004; Lacy, Glenna, Biscotti, Welsh & Clancy, 2014, and INE, 2014).

According to the objective of our work, we have grouped the benefits, understood as the incentives to perform R&D. The Motivation to Engage Index (MOEI) has been created 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). The risks have been grouped in the mitigation index, as they are related to the obstacles to R&D. The Mitigation of Engagement Index (MIEI) 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 low values obtained in the variance inflation factor (VIF) indicate that no significant multicollinearity exists among the four indices (VIF values: PPI = 1.26; NPI = 1.16; MOEI = 1.23; MIEI = 1.39).

The third dimension covers Attitudes towards the role played within firms by S&T, 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. These topics are recurrent in PUS questionnaires, not referring to R&D but to S&T in general (Castell et al., 2014; European Commission, 2010).

Consistent with that conceptual formulation, the answers have been used to build four indices based on the following average scores: a) TRUST in scientists, for items 1, 3 and 8; b) CONTROL over R&D and researchers within companies: for items 2 and 5; c) EXPECTATIONS in science: for items 4 and 7; and d) Value of SCIENTIFIC KNOWLEDGE: 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.

Control variables

Existing literature has shown that the effect of these factors may be mediated by firm's characteristics and industrial structure (Shefer & Frenkel, 2005). We additionally

include two firm- and industrial-level variables potentially related to company decisions to engage in innovation: firm age and a sector aggregation of the CNAE (the Spanish acronym for Spain's National Classification of Economic Activities): agriculture (primary sector), industry, energy, construction, and services.

Data analysis

A Student's t-test has been performed to explore the differences in the explanatory variables between innovative and non-innovative companies (Table 4). We have reinforced this preliminary analysis by subsequently exploring whether the perceptions of science and R&D differ according to firm size, with the aim being to identify a possible dependency between them. We have therefore conducted non-parametric tests to detect differences in the perception variables between innovation engaged and non-engaged firms in each of the established size groups (Table 5) and the size of companies either engaged or non-engaged in innovation (Table 6).

A logistic regression analysis has been conducted to explore the relationships between multiple explanatory economic and perception variables on firms' engagement in innovation (Table 7). The coefficients obtained for those explanatory variables with suitable levels of significance estimate their relationship with engagement in innovation activities. Exp β coefficients above 1 indicate that an increase in the explanatory variable is related to an increase in the likelihood of a firm performing innovation activities. This provides a profile of the firms engaging in these processes. We used the Czarnitzki and Hottenrott (2011) approach to extend this baseline logistic regression model in order to consider the possible variation of perception variables with firm size. Perception variables were interacted with four dummy variables (0 = does not belong to this size class, 1 = belongs to this size class) that assign each firm to one of the four size groups. This leads to four interaction terms for each perception variable:

$$PERCEPTION_variable \times SIZE_ECO_X$$

with PERCEPTION_variable (PPI, NPI, MOEI, MIEI, TRUST, CONTROL, EXPECTATIONS, SCIENTIFIC KNOWLEDGE)

with X = 1...4.

These new variables allow splitting the perception variables into four categories according to size categories and modelling their heterogeneous effects for firms of different sizes. We estimated a regression model for the innovation variable through these interaction terms of the perception variables with firm size (Table 8). The possible monotonic relationship of the coefficients of the new variables would allow us to conclude on the influence size has on the perceptions of corporate science and R&D activities (Czarnitzki et al., 2011).

In addition, we tested the possible reverse relationship between the view business sector has of science, R&D and innovation, and previous innovation experience. For this purpose, we followed the approach by Tiwari, Mohnen, Palm, and van der Loef (2007) and regressed economic characteristics and innovation experience on the perception positions (Table 9).

Dataset availability

Name: Survey 'Scientific Culture, Perception and Attitudes towards Science and Innovation in the Spanish Business Sector'. Language: English and Spanish. Content: Survey technical details, Codebook and coding standards followed for all variables, Syntax, Microdata ASCII, Questionnaire. Data format: ASCII (no particular software requirements for opening, visualising and/or using these data. Original database has been created with SPSS software).

<http://hdl.handle.net/10261/223009>

<http://dx.doi.org/10.20350/digitalCSIC/12713>.

Results

Over half of Spanish companies (55.1%) have engaged in innovation. The Student's t-test provides the characteristics of innovative and non-innovative firms (Table 4). Managers of innovation engaged firms have a better image of science and are more motivated to perform R&D. These firms are less leveraged and more profitable than non-engaged ones in terms of resource availability measured by ROA. Managers of non-innovative firms have a greater perception of the risks associated with these activities, which may act as mitigators of engagement. None of the attitude variables show

statistically significant differences between innovative and non-innovative firms. These results provide initial support for the proposition that the perception of science and R&D are not independent of firms' innovation-related behaviour.

Table 4. Differences in the explanatory variables between innovative and non-innovative companies

	Innovation	
	Yes	No
n (%)	389 (55.1%)	315 (44.6%)
	Mean (Standard error of the mean)	
<i>Ideas and values associated with science</i>		
Positive Perception Index (PPI)	4.20* (.04)	4.10 (.04)
Negative Perception Index (NPI)	1.92 (.05)	2.23* (.05)
<i>Willingness to engage in R&D activities</i>		
Motivation to Engage Index (MOEI)	4.26* (.03)	3.97 (.04)
Mitigation of Engagement Index (MIEI)	2.12 (.03)	2.32* (.04)
<i>Attitudes</i>		
TRUST in scientists	3.67 (.04)	3.60 (.04)
CONTROL over R&D and researchers within companies	3.05 (.05)	2.99 (.04)
EXPECTATIONS in science	2.78 (.04)	2.84 (.04)
Value of SCIENTIFIC KNOWLEDGE	2.93 (.04)	2.84 (.05)
<i>Size</i>		
Sales	3188.77 (1986.89)	1012.64 (200.43)
Total assets	4551.37 (3430.50)	1538.59 (457.94)
<i>Resources capability</i>		
Return on assets (ROA)	.03* (.01)	.004 (.01)
Return on equity (ROE)	.13 (.02)	.03 (.12)
Profit margin (PM)	-.26 (.52)	-.24 (.14)
Asset turnover (AT)	1.64 (.06)	1.51 (.08)
<i>Leverage</i>		
Leverage (LEV)	64.52 (2.02)	76.83* (6.04)
Mean values were compared to a Student's t test with Bonferroni correction		
* Significant differences are reported at p < .1 in the two-sided test of equality for column means, assuming equal variances.		

Table 5 shows differences in the perception variables between innovation engaged and non-engaged firms in each one of the size groups. Table 6 shows differences in the perception variables between companies of different sizes in firms either engaged or non-engaged in innovation. The non-parametric analyses show significant differences both within and between size groups in certain perception variables, although they do not allow us to effectively generalise the existence of a monotonic relationship between perception variables and size.

Table 5. Mann-Whitney test results for the differences in the perception variables between innovative and non-innovative firms in each of the established size groups

Variable	SIZE_ECO							
	Micro		Small		Medium		Large	
	Innovation							
	Yes	No	Yes	No	Yes	No	Yes	No
Positive Perception Index (PPI)	99.46**	83.51	144.36***	119.22	94.75	101.75	25.31	22.54
Negative Perception Index (NPI)	70.75***	108.93	126.42	134.33	94.14	103.05	20.56	34.07***
Motivation to Engage Index (MOEI)	97.92	89.78	146.96***	115.64	106.40***	77.13	27.97***	16.07
Mitigation of Engagement Index (MIEI)	81.19	103.86***	124.62	137.14	92.03	107.50*	19.75	36.04***
TRUST in scientists	103.86**	84.78	128.01	134.83	103.51**	83.25	28.35***	15.14
CONTROL over R&D and researchers within companies	94.56	92.60	131.43	131.56	99.23	92.29	25.82	21.29
EXPECTATIONS in science	87.57	98.49	138.47*	123.00	92.87	105.72	25.57	21.89
Value of SCIENTIFIC KNOWLEDGE	99.57	88.39	128.11	134.74	100.23	90.18	25.76	21.43
***, **, * = statistically significant at the 99%, 95% and 90% levels								

Table 6. Kruskal-Wallis test results for the differences in the perception variables between companies of different sizes in firms engaged and non-engaged in innovation

Variable	Innovative companies					Non-innovative companies				
	SIZE ECO									
	Micro	Small	Medium	Large	Sig.	Micro	Small	Medium	Large	Sig.
Positive Perception Index (PPI)	154.71	141.10	176.25	163.11		201.73	189.45	179.55	197.47	*
Negative Perception Index (NPI)	175.78	141.50	141.47	168.86	***	173.96	203.73	196.25	138.54	**
Motivation to Engage Index (MOEI)	171.53	153.35	146.25	101.29		185.73	190.97	192.51	181.78	**
Mitigation of Engagement Index (MIEI)	160.58	149.48	151.65	193.04	***	183.84	201.19	197.74	127.90	
TRUST in scientists	164.21	164.44	137.90	96.14	**	221.48	173.49	186.11	182.88	**
CONTROL over R&D and researchers within companies	148.82	159.81	161.42	147.32		177.28	185.57	196.30	208.66	
EXPECTATIONS in science	171.59	140.86	167.54	137.29		186.60	194.63	180.61	200.93	**
Value of SCIENTIFIC KNOWLEDGE	146.34	166.03	145.81	174.82	**	190.79	179.73	183.69	245.44	
***, ** * = statistically significant at the 99%, 95% and 90% levels										

A summary of the results for the baseline and extended regression models is provided in Tables 5 and 6, respectively. The extended model including the interaction variables record better results in terms of explained variance percentages (Nagelkerke R^2 value).

Table 7 shows that science's close association with negative aspects (NPI) is linked to a lower engagement in innovation. MOEI and MIEI have a positive and negative relationship, respectively, with the probability of innovation engagement. This indicates that innovation engagement is associated with those companies that do have a positive appraisal of R&D for the firm through the recognition of the benefits arising from investment in R&D activities, and that companies are less prone to innovate when they are aware of the risks involved in R&D investment.

As for economic variables, the move from categories 1 to 2 in SIZE_ECO (i.e., from micro to small enterprises) is not significantly associated with increased engagement in innovation. However, the move to categories 3 and 4 (medium and large enterprises) certainly is, and will double or even almost triple innovation engagement (it increases by 101% and 177%, respectively). The positive effect of LEV and negative of LEV*LEV confirms that the relationship between leverage and engagement in innovation is positive up to a certain value of leverage, beyond which it is negative, that is, it has an inverted U-shaped distribution. This means that engagement in innovation activities is more closely associated with medium and large enterprises having a level of debt below a certain threshold, and decreases in micro ones and those more heavily indebted.

In the baseline model, firm size determined the probability of engaging in innovation only in certain size groups, and especially in medium and large firms. The regressions with interaction terms (Table 8) evidence that the coefficients in only some of the new variables have a monotonic relationship. The effects of the $PPI \times SIZE$ and $MOEI \times SIZE$ monotonically decrease and increase, respectively. Both effects are statistically significant above a certain firm size. Thus, we found that the differences in perception associated with size are significant only in very specific cases.

Table 7. Estimation results for baseline logistic regressions on firms' engagement in innovation activities

	B	Standard Error	Wald	Sig.	Exp(B) (Odds ratio)	Percent increase odds (%)
PPI	-0.19	0.13	2.25	0.134	0.82	-17.46
NPI	-0.25	0.10	7.07	0.008	0.77	-22.48
MOEI	0.76	0.15	23.93	0.000	2.13	113.35
MIEI	-0.29	0.14	4.17	0.041	0.75	-24.91
TRUST	-0.10	0.14	0.56	0.455	0.90	-9.76
CONTROL	0.13	0.11	1.26	0.262	1.14	13.73
EXPECTATIONS	-0.17	0.11	2.36	0.124	0.84	-15.91
SCIENTIFIC KNOWLEDGE	0.11	0.12	0.93	0.335	1.12	12.21
SIZE_ECO(1) (micro; benchmark)			21.55	0.000		
SIZE_ECO(2) (Small vs micro)	-0.18	0.23	0.61	0.433	0.84	-16.31
SIZE_ECO(3) (Medium vs micro)	0.70	0.25	7.92	0.005	2.01	100.98
SIZE_ECO(4) (Large vs micro)	1.02	0.38	7.09	0.008	2.77	176.98
zROA	-0.08	0.13	0.42	0.516	0.92	-8.18
zROE	0.07	0.09	0.69	0.404	1.07	7.40
zPM	0.002	0.13	0.00	0.989	1.00	0.18
AT	0.07	0.08	0.77	0.381	1.07	6.84
zLEV	0.45	0.15	9.24	0.002	1.57	57.47
zLEV*zLEV	-0.05	0.01	12.15	0.000	0.95	-4.66
Firm age	-0.004	0.01	0.17	0.679	1.00	-0.38
Sector (Agriculture, primary sector; benchmark)			17.04	0.002		-100.00
Sector (Industry)	-0.48	0.55	0.77	0.380	0.62	-38.15
Sector (Energy)	-0.04	1.15	0.001	0.975	0.96	-3.50
Sector (Construction)	-1.67	0.54	9.36	0.002	0.19	-81.10
Sector (Services)	-0.70	0.52	1.82	0.177	0.50	-50.32
Constant	-0.90	1.28	0.50	0.480	0.40	-59.53
Nagelkerke's R ²	0.21					

Table 8. Estimation results for extended logistic regressions on firms' engagement in innovation and PERCEPTION*SIZE_ECO interactions

Variable	B	Standard Error	Wald	Sig.	Exp(B) (Odds ratio)	Percent increase odds (%)
PPI×SIZE_ECO (Micro)	0.21	0.24	0.76	0.383	1.23	23.52
(Small)	-0.11	0.20	0.29	0.590	0.90	-10.19
(Medium)	-0.60	0.28	4.58	0.032	0.55	-45.41
(Large)	-2.90	1.06	7.53	0.006	0.05	-94.51
NPI×SIZE_ECO (Micro)	-0.89	0.21	17.59	0.000	0.41	-58.79
(Small)	-0.06	0.16	0.12	0.733	0.94	-5.46
(Medium)	-0.01	0.18	0.01	0.935	0.98	-1.45
(Large)	-0.56	0.56	0.93	0.334	0.57	-42.79
MOEI×SIZE_ECO (Micro)	0.35	0.32	1.16	0.281	1.41	41.51
(Small)	0.94	0.27	12.23	0.000	2.57	156.63
(Medium)	1.07	0.29	14.03	0.000	2.92	192.04
(Large)	2.33	0.91	6.51	0.011	10.24	923.98
MIEI×SIZE_ECO (Micro)	-0.16	0.27	0.33	0.566	0.86	-14.43
(Small)	-0.05	0.22	0.05	0.819	0.95	-5.03
(Medium)	-0.19	0.28	0.45	0.504	0.83	-17.19
(Large)	-0.89	0.64	1.96	0.162	0.41	-59.01
TRUST×SIZE_ECO (Micro)	0.68	0.32	4.69	0.030	1.98	98.05
(Small)	-0.66	0.22	9.00	0.003	0.52	-48.18
(Medium)	0.10	0.28	0.12	0.724	1.10	10.53
(Large)	1.49	0.68	4.75	0.029	4.45	344.97
CONTROL×SIZE_ECO (Micro)	0.16	0.22	0.51	0.473	1.18	17.57
(Small)	-0.04	0.18	0.05	0.830	0.96	-3.75
(Medium)	0.19	0.21	0.79	0.375	1.20	20.55
(Large)	0.84	0.50	2.83	0.092	2.32	131.57
EXPECTATIONS×SIZE_ECO (Micro)	-0.77	0.25	9.19	0.002	0.46	-53.53
(Small)	0.28	0.21	1.84	0.175	1.33	32.87
(Medium)	-0.35	0.21	2.72	0.099	0.71	-29.45
(Large)	-0.10	0.48	0.04	0.833	0.90	-9.70
SCIENTIFIC KNOWLEDGE×SIZE_ECO (Micro)	0.14	0.23	0.38	0.539	1.15	15.32
(Small)	-0.05	0.21	0.07	0.791	0.95	-5.39
(Medium)	0.29	0.23	1.60	0.205	1.34	33.56
(Large)	0.38	0.51	0.54	0.461	1.46	45.74
zROA	-0.09	0.14	0.38	0.536	0.91	-8.50
zROE	0.12	0.09	1.60	0.206	1.13	12.68
zPM	-0.01	0.14	0.01	0.926	0.99	-1.25
AT	0.13	0.08	2.53	0.112	1.14	14.07
zLEV	0.38	0.17	5.21	0.023	1.46	45.95
zLEV×zLEV	-0.04	0.01	7.66	0.006	0.96	-4.12
Firm age	0.00	0.01	0.00	0.970	1.00	-0.04
Sector (Agriculture, primary sector; benchmark)			13.72	0.008		-100.00
(Industry)	-0.65	0.58	1.25	0.264	0.52	-47.80
(Energy)	-0.16	1.20	0.02	0.895	0.85	-14.64
(Construction)	-1.70	0.59	8.38	0.004	0.18	-81.72
(Services)	-0.73	0.55	1.73	0.188	0.48	-51.74
Constant	-1.36	1.40	0.95	0.33	0.25	-74.46
Nagelkerke's R ²	0.31					

Overall, the results show that, after controlling by sector and firm's age, firms' engagement in innovation is related to both perception and economic variables. The absence of a negative perception of science (NPI) together with a positive motivation for the execution of R&D activities (MOEI), expressed through the recognition of the benefits derived from carrying out R&D activities, are both characteristic features of innovative companies. Therefore, companies whose managers do not have a negative perception of science and who appreciate the benefits of investing in R&D –thus being positively motivated to implement R&D at their company- and which are less worried about the risks it may involve (MIEI) are more prone to engage in innovation activities, and this is the case mainly among medium and large enterprises having a level of leverage below a certain threshold. Firm age is not associated with innovation engagement. Construction companies are significantly less engaged in innovation than companies in other sectors.

Table 9 shows the multiple linear regression results for managers' perceptions of science, carried out to explore the expected mutual relationship between innovation experience and economic characteristics and the perception of science and R&D. A certain experience in engagement in innovation affects the NPI, MOEI and MIEI variables, respectively. Regarding firm's economic capacity and structural characteristics, the results show only a limited influence in perception variables. Managers in large firms give more value to scientific knowledge than other companies and tend to underestimate negative science-related aspects. Conversely, as companies become older, their managers have a more negative perception of science and tend to give less value to the role and relevance of scientific knowledge for corporate decision-making.

Table 9. Estimation results for regressions on managers' perception of science

Variables	NPI	MOEI	MIEI	SCIENTIFIC KNOWLEDGE
	Standardised β (t)			
Innovation	-0.16*** (-4.20)	0.24*** (6.26)	-0.14*** (-3.55)	0.06 (1.42)
SIZE_ECO (Micro)	0.05 (1.19)	0.03 (0.71)	0.003 (0.06)	-0.04 (-0.93)
SIZE_ECO (Medium)	0.01 (0.25)	-0.02 (-0.53)	0.02 (0.42)	-0.01 (-0.25)
SIZE_ECO (Large)	-0.08* (-1.86)	-0.05 (-1.29)	-0.05 (-1.14)	0.09** (2.29)
Firm age	0.08** (1.99)	0.03 (0.73)	-0.04 (-0.93)	-0.08** (-1.96)
Sector (Agriculture, primary sector)	0.05 (1.34)	-0.04 (-1.02)	0.01 (0.15)	-0.03 (-0.77)
Sector (Industry)	0.07 (1.35)	-0.09* (-1.82)	-0.03 (-0.59)	-0.07 (-1.51)
Sector (Energy)	0.004 (0.09)	-0.01 (-0.39)	-0.01 (-0.33)	0.01 (0.27)
Sector (Services)	0.04 (0.83)	-0.09* (-1.70)	-0.06 (-1.10)	-0.13** (-2.43)
R ²	.042	.057	.028	.026
F-value	3.38	4.65	2.22	2.07
P-value	.000	.000	.019	.030

***, **, * = statistically significant at the 99%, 95% and 90% levels
 SIZE_ECO (Small) and Sector (Construction) have been excluded from the model due to collinearity (Tolerance < 0.1)

Regarding the results for the determinants of the probability of engaging in R&D activities (Table 7), a mutual relationship is evidenced between innovation experience and NPI, MOEI and MIEI.

Hypothesis H1 is confirmed, as engagement in innovation activities is a more distinctive feature of those companies whose leaders manifest a less negative perception of science. H2a is confirmed, as innovation engagement increases when entrepreneurs and company managers become aware of the benefits of investing in R&D. H2b is also confirmed, as awareness of the risks it might have for firms, is related to a reduced propensity to innovate. This is not the case with attitudes towards the roles played within firms by science and technology, R&D, scientific knowledge, and scientists, which have no relationship with innovation, so H3 could not be confirmed. The results provide evidence to show that the benefits and risks of investing in R&D are revealed by the innovation experience and those firms are more aware of them precisely because of that experience.

Discussion and conclusions

Corporate innovation decisions are not just a matter of money. Our analysis confirms the combined effect of a firm's economic characteristics and perception of science on innovation engagement. It shows that engagement of firms in innovation activities is related both to their capability for actually undertaking the processes and to the propensity towards them. The results obtained through the conjunction of economic variables and the perception of science are consistent with the thesis that the rate of innovation for any social group depends both on its capability to carry it out and on its will to innovate. This involves not only tangible technological investment but also a culture of science, R&D and innovation.

The results of the SCe survey show that the propensity to undertake innovation processes in businesses would be directly linked to the perception of science and R&D, particularly with the following:

- A positive perception of the benefits stemming from the investment in R&D (e.g., long-term economic benefits, competitive advantage, improved market image, and job generation within the company itself) that motivates engagement.
- Least concern of business R&D as a risky and uncertain investment and of risks which might be entailed in participating in R&D (e.g., risk of job loss, waste of time, and risks for health and the environment).
- The absence of a negative image of science as something boring and not to be trusted.

The presence of these three factors as a combination related to engagement in innovation activities is a novelty that we had not observed in a previous study (González-Bravo, López-Navarro & Rey-Rocha, 2020) in relation to firms' engagement in R&D activities. The perception variables associated with innovation combine the positive appraisal of the benefits of R&D investment by firms acquiring extramural R&D, with the absence of negative perceptions of science shown by entrepreneurs and managers of companies performing R&D activities.

Thus, the results here confirm that in innovative companies, entrepreneurs and managers are aware of the benefits for the company of investing in R&D, but instead do

not place much concern in the risk involved on it, and they have fewer negative perceptions towards science than their counterparts in non-innovative undertakings.

It is also worth noting that there is no relationship between engagement in innovation and business attitudes towards scientists, their work and scientific knowledge. Although the positive perception of the benefits that investment in R&D can bring to companies is directly related to innovative activity, this is not the case with the perception of how it should be developed in the intramural or extramural projects companies participate in -with regard to trust in scientists and research groups, the degree of control over R&D projects, the expectations placed on science and technology- and on the use of scientific knowledge within the company. This may be due simply to the different level of abstraction with which survey questions have been posed. In general, there is less positioning when entrepreneurs respond to more general questions, such as what they think about scientists and the role they should ideally develop in the company. However, when asked about more tangible issues such as risks and the benefits of investing in R&D or innovation, the answers reflect a greater difference between those engaged in innovation and those not.

Differences in the perception of science and R&D may also be partially linked to firm size. Even though there are differences within and between size classes in certain perception variables, the results do not allow us to effectively generalise the existence of a monotonic relationship between perception variables and size.

Variables associated with the perception of the benefits and risks of R&D (MOEI and MIEI) seem to be influenced by experience in innovation. This is important because it indicates that barriers associated with the benefits and risks of investing in R&D are revealed (D'Este, Iammarino, Savona & von Tunzelmann, 2012) once firms become involved in innovation as a form of learning that can either motivate or mitigate their engagement accordingly.

If the perception of science is deterring companies from engaging in innovation, then action pathways for promoting innovation engagement can be determined by the ability to give companies confidence in R&D and foster a culture of science and innovation. If these are revealed barriers, then they would be indicating companies' greater awareness of their processes based on the knowledge acquired by their experience. Our results allow us to consider the consistency of the revealed variables for the

perception of science, mainly for their negative evaluation. However, this cannot be said for the perceptions of the benefits and risks of engaging in R&D, which are associated with the decision to engage in innovation. Thus, a proactive attitude towards R&D is linked to the consideration of a long-term scenario in which companies estimate the benefits and effects that could be derived from innovation engagement.

In addition, results show that innovation in the business sector is not so much a matter of the resources available as of another series of aspects linked to size. In fact, none of the variables strictly linked to return (return on assets and return on equity) or the measures that reflect efficiency (profit margin and asset turnover, in which sales is one of their components) are related to engagement in innovation activities. These results may seem surprising given that a natural relationship seems to be assumed between size and performance (measured through variables such as ROA, profit margin, or any of the income indicators). Nevertheless, studies such as the one by Capón, Farley and Hoening (1990), who performed a meta-analysis of the research relating organizational factors to financial performance, have not found a significant relationship between these variables.

Instead, innovation is associated with companies of a certain scale –determined by the combination of sales and total assets–whereby large and medium-sized companies, as opposed to micro ones, are more prone to engage in innovation. This confirms the non-linearity of this relationship previously reported by different authors (Symeonidis, 1996; Mohnen & Dagenais, 2002). The link between large size and innovation could be understood as a greater capacity to absorb and diversify risks if the process fails, as authors such as Camisón-Zorzona, Lapiedra-Alcamí, Segarra-Ciprés and Boronat-Navarro (2004) argue.

Findings on the relationship between firm size and engagement in innovation confirm the disadvantage faced by micro and small companies in the market -except in very exceptional circumstances or sectors (Ugur, Trushin, Solomon & Guidi, 2016) when it comes to innovating (Mohnen et al., 2002). This leads to two possible measures in the field of research policy: either encouraging existing micro and small companies to join together or associate in larger structures, or assuming the overabundance of small companies as a structural feature of the Spanish business sector, and then providing specific and strong support to develop the conditions that favour their engagement in innovative activities. Nevertheless, we should remember that innovating needs more than

having a certain size and resources, as it requires combining them with a series of intangible factors related to the attitude and predisposition towards science and investment in R&D. It is therefore important that neither public policies –at macro level– nor entrepreneurs and managers –at micro level– should focus exclusively on structural issues such as size or resources, as they should also address subjective issues in order to conquer the innovation terrain.

Companies' financial needs for innovating are consistent with the evidence obtained with respect to some of the economic variables considered here. The results show that innovative companies tend to be more indebted. This is consistent with the fact that the financial effort of engaging in innovation projects generally calls for additional funds. However, this direct relationship is not continuous, although a firm's level of debt is directly related to the propensity to engage in innovation up to a certain extent, after which it becomes a handicap, which is consistent with the position of authors such as Baumann and Kritikos (2016).

The above results allow us to refer to structure and financing capacity, rather than to the generation of internal resources, as factors related to engagement in innovation, as none of the variables associated with profits is statistically significant. However, this should not be interpreted as meaning that companies can undertake innovation projects without having a minimum capacity to obtain positive results.

This study is framed within our research on the role played by scientific culture and the perception of science and R&D, together with firms' structural, economic and financial characteristics, in explaining the engagement of companies in R&D and innovation. It is the first large sample study of the relationship between the perception of science and R&D and engagement in innovation in the business sector, so its findings should be confirmed by other methods and in other settings and contexts.

Notwithstanding, this study provides some important implications for the management of innovation in the business sector. Our findings highlight the role of managers' perceptions and attitudes towards science and R&D in directing a firm's innovation activities, and the effects of organizational characteristics on innovation engagement. It stresses that innovation is related with entrepreneurs and managers having a perception of science and R&D that paves the way for the allocation of a firm's resources to activities oriented towards knowledge generation and innovation. Instead,

consideration of R&D as a risky endeavour for companies does not seem to shift them away from the innovation path.

This study confirms that entrepreneurs and managers' attitude towards science and R&D is related to firms' engagement (or not) in innovation, suggesting that their attitudes and behaviour in relation to science and investment in R&D should be given a more prominent role in S&T and innovation studies and in developing models of innovation in the future. More research is required to enhance our understanding of these effects, and innovation research will be enriched if more studies consider cultural factors, including the culture of science and innovation.

Spain has been classified as a 'moderate innovator' in the latest European Innovation Scoreboards (see European Union, 2020, and previous editions). The results obtained here are still important regarding the way to address possible initiatives aimed at encouraging innovation in the Spanish business sector. The negative perception of science and the benefits of R&D by entrepreneurs and managers seem to be an obstacle for companies to engage in innovation projects. It is therefore important to stress the need to nurture a culture of science and R&D within the business sector. Successful innovation may therefore require the hiring of managers with no negative attitudes towards science and positively motivated towards investment in R&D.

Furthermore, when interpreting the data and establishing possible comparisons with other studies, it should be noted that this research refers to the undertaking of innovation activities, so we do not capture other facets of the innovation construct, such as adoption or implementation.

Moreover, our results and the conclusions we have drawn concern the particular sample we have studied, showing the general picture in a single country, and should not be considered predictive of the inferences that might be drawn for other innovation systems. This design does 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, with further studies being carried out with larger communities in different (geographic and thematic) contexts in order to take into account different models of innovation organization. In turn, there are important inter-sectoral differences with respect to firms' innovation, and these differences are also likely to exist

in the culture of science and the perception of R&D. Thus, more detailed cross-sectoral analyses of data will shed light on the differences between economic sectors.

Funding

This work was supported by the Spanish Ministry of Economy, Industry and Competitiveness (research project CSO2014-53293-R) and the Spanish Foundation for Science and Technology, FECYT (research project FCT-16-10889).

Conflicts of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Acknowledgements

This study would not have been possible without the collaboration of the rest of the researchers in the S_{Ce} team. María Rosario Osuna (Universidad de Salamanca), Pura Ribas and María José Cuesta (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT), and Rafael Castro, Nadia Fernández de Pinedo, Félix Fernando Muñoz and Patricio Sáiz (Universidad Autónoma de Madrid). We acknowledge assistance from José Manuel Rojo, Yasmina González, M^a Ángeles Toribio and Concepción Murillo, from the Statistical Analysis Unit at the Centre for Human and Social Sciences (CCHS-CSIC), and Laura Barrios, at CSIC Information Technology Area. We express our appreciation to Aitor Vallejo, Nagore Fernández and the entire Quor team for their collaboration in sample design and the telephone survey. Special thanks are expressed to all survey participants.

References

- Baldrige, J.V., & Burnham, R.A. (1975). Organizational innovation, individual, organizational, and environmental impacts. *Administrative Science Quarterly*, 20(2), 165-176.

- Bauer, M.W. (2009). The evolution of public understanding of science—discourse and comparative evidence. *Science, Technology and Society*, 14(2), 221-240.
- Bauer, M.W. (2014). Cultura científica y sus indicadores. Una revisión actualizada. [Scientific culture and its indicators. An updated review] In B. Laspra, & E. Muñoz (Coord.), *Culturas científicas e innovadoras. Progreso social* [Scientific and innovative cultures. Social progress], (pp. 101-126). Buenos Aires: Eudeba.
- Bauer, M.W., & Falade; B. (2014). Public Understanding of Science: Survey Research Around the World. In M. Bucchi, & B. Trench (Eds.), (pp. 140-159). New York: Routledge.
- Bauer, M.W., & Suerdem, A. (2016). Relating ‘science culture’ and innovation. In *OECD blue sky forum on science and innovation indicators*. Ghent, Belgium, 19-21 September.
- Bauer, M.W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey Research? Liberating and expanding the agenda. *Public Understanding of Science*, 16(1), 79-95.
- Baumann, J., & Kritikos, A.S. (2016). The link between R&D, innovation and productivity: Are micro firms different? *Research Policy*, 45(6), 1263-1274.
- Busse, R. (2014). Is culture driving innovation? A multi-national quantitative analysis. *Human Systems Management*, 33(3), 91-98.
- Camisón-Zornoza C., Lapiedra-Alcamí, R., Segarra-Ciprés, M., & Boronat-Navarro, M. (2004). A meta-analysis of innovation and organizational size. *Organization Studies*, 25(3), 331-361.
- Capón, N., Farley, J.U., & Hoenig, S. (1990). Determinants of financial performance: A meta-analysis. *Management Science*, 36(10), 1143-1159. <https://doi.org/10.1287/mnsc.36.10.1143>.
- Castell, S., Charlton, A., Clemence, M., Pettigrew, N., Pope, S., Quigley, A., Navin Shah, J., & Silman, T. (2014). *Public Attitudes to Science*. London: Department for Business, Innovation & Skills.
- Coad, A., Pellegrino, G., & Savona, M. (2016). Barriers to innovation and firm productivity. *Economics of Innovation and New Technology*, 25(3), 321-334.
- Cornell University, INSEAD, WIPO (2015). *The Global Innovation Index 2015: Effective innovation policies for development*. Fontainebleau, Ithaca, and Geneva.
- Czarnitzki, D., & Hottenrott, H. (2011). R&D investment and financing constraints of small and medium-sized firms. *Small Business Economics*, 36(1), 65-83.
- Damanpour, F. (1991). Organizational innovation: A meta-analysis of effects of determinants and moderators. *The Academy of Management Journal*, 34(3), 555-590.
- Damanpour, F., & Schneider, M. (2006). Phases of the adoption of innovation in organizations: Effects of environment, organization and top managers. *British Journal of Management*, 17(3), 215-236.
- D’Este, P., Iammarino, S., Savona, M., & von Tunzelmann, N. (2012). What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, 41(2), 482-488.

- Dobni, C.B. (2008). Measuring innovation culture in organizations: The development of a generalized innovation culture construct using exploratory factor analysis. *European Journal of Innovation Management*, 11(4), 539-559.
- Ekvall, G., & Arvonen, J. (1991). Change-centered leadership: An extension of the two-dimensional model. *Scandinavian Journal of Management*, 7(1), 17-26.
- European Commission. (2004). *Innobarometer*. Luxembourg: Office for Official Publication of the European Communities.
- European Commission. (2010). *Special Eurobarometer 340. Science and Technology*. Luxembourg: Office for Official Publication of the European Communities.
- European Union (2020) *European Innovation Scoreboard 2020*. Luxembourg: Publications Office of the European Union. This and previous editions retrieved 10/03/2021 from https://ec.europa.eu/growth/industry/policy/innovation/scoreboards_en.
- Fernández-Esquinas, M., van Oostrom, M., & Pinto H. (2017). Key issues on innovation, culture and institutions: Implications for SMEs and micro firms. *European Planning Studies*, 25(11), 1897-1907.
- Geels, F.W. (2004). From Sectoral Systems of Innovation to Socio-Technical Systems: Insights about Dynamics and Change from Sociology and Institutional Theory. *Research Policy* 33(6-7), 897-920. doi:10.1016/j.respol.2004.01.015.
- González-Bravo, I., López-Navarro, I., & Rey-Rocha, J. (2020). Is corporate R&D simply a matter of money? The combined effect of a firm's economic characteristics and its perception of science. *Industry and Innovation*, <https://doi.org/10.1080/13662716.2020.1792273>.
- Gopalakrishnan, S., & Damanpour, F. (1997). A review of innovation research in economics, sociology and technology management. *Omega*, 25(1), 15-28.
- Hambrick, D.C., & Mason, P.A. (1984). Upper Echelons: The Organization as a Reflection of its Top Managers. *Academy of Management Review* 9(2), 193-206.
- Harrison, R., Jaumandreu, J., Mairesse, J., & Peters, B. (2014). Does Innovation Stimulate Employment? A Firm-Level Analysis Using Comparable Micro-Data from Four European Countries. *International Journal of Industrial Organization*, 35, 29-43.
- Hitlin, S., & Piliavin, J. A. (2004). Values: Reviving a Dormant Concept. *Annual Review of Sociology*, 30: 359-393.
- Hofstede, G. (2001). *Culture's Consequences: Comparing Values, Behaviors, Institutions and Organizations Across Nations*. Sage, Thousand Oaks, CA.
- INE, Instituto Nacional de Estadística (2014). *Encuesta sobre Innovación en las Empresas [Technological Innovation Survey]*. Madrid: Instituto Nacional de Estadística.
- Jaruzelski, B., Dehoff, K., & Bordia, R. (2005). Money Isn't Everything. *Technology & Innovation*, 41. <https://www.strategy-business.com/article/05406?gko=3705a>. Accessed 10 March 2021.
- Kaasa, A. (2016). Culture as a possible factor of innovation: Evidence from the European Union and neighbouring countries. In D. Richler (Ed.), *Re-thinking Diversity*, (pp. 83-107). Wiesbaden: Springer.

- Kaasa, A., & Vadi, M. (2010). How does culture contribute to innovation? Evidence from European countries. *Economics of Innovation and New Technology*, 19(7), 583-604.
- Kenney, M., & Goe, W.R. (2004). The role of social embeddedness in professorial entrepreneurship: A comparison of electrical engineering and computer science at UC Berkeley and Stanford. *Research Policy*, 33(5), 691-707.
- Lacy, W.B., Glenna, L.L., Biscotti, D., Welsh, R., & Clancy, K. (2014). The two cultures of science: implications for university-industry relationships in the US agriculture biotechnology. *Journal of Integrative Agriculture*, 13(2), 455-466.
- Madrid-Guijarro, A., Garcia, D., & Van Auken, H. (2009). Barriers to Innovation among Spanish Manufacturing SMEs. *Journal of Small Business Management*, 47(4), 465-488.
- Meyer, J.W., & Rowan, B. (1977). Institutionalized Organizations: Formal Structure as Myth and Ceremony. *The American Journal of Sociology*, 83(2), 340-363.
- Mohnen, P., & Dagenais, M. (2002). Towards an innovation intensity index: The Case of CIS 1 in Denmark and Ireland. In A. Kleinknecht, & P. Mohnen (Eds.), *Innovation and firm performance. Econometric explorations of survey data* (pp. 3-30). New York: Palgrave.
- Muñoz van den Eynde, A., Laspra, B., & Díaz García, I. (2017). Exploring the Image of Science: Neural Nets and the PIKA Model. *Advances in Research*, 9(5), 1-19.
- Pellegrino, G., & Savona, M. (2013). Is Money All? Financing versus Knowledge and Demand Constraints to Innovation. *Working Paper Series*, 2013-021. <http://dx.doi.org/10.2139/ssrn.2341095>.
- Powell, W., & Colyvas, J.A. (2008). The New Institutionalism. In S.R. Clegg, & J.R. Bailey (Eds.), *The International Encyclopedia of Organization Studies*, (pp. 975-979). Thousand Oaks: Sage.
- Quintanilla, M.A. (2005a) La construcción del futuro [Building the future]. In M.A. Quintanilla (Ed.), *Tecnología: un enfoque filosófico y otros ensayos de filosofía de la tecnología* [Technology: A philosophical approach and other essays on the philosophy of technology] (pp. 187-204). Mexico: FCE.
- Quintanilla, M.A. (2005b) Cultura tecnológica e innovación [Technological culture and innovation]. In *Tecnología: un enfoque filosófico y otros ensayos de filosofía de la tecnología* [Technology: A philosophical approach and other essays on the philosophy of technology] (pp. 247-261). Mexico: FCE.
- Rey-Rocha, J., & López-Navarro, I. (2016). The SCe questionnaire: Scientific culture, perception and attitudes towards science and innovation in the Spanish business sector. Bilingual edition Spanish/English. Retrieved 10/03/2021 from Digital.CSIC, the repository of the Spanish National Research Council. <http://hdl.handle.net/10261/171841>.
- Robertson, T S., & Gatignon, H. (1998). Technology Development Mode: A Transaction Cost Conceptualization. *Strategic Management Journal*, 19(6), 515-531.
- Shane, S. (1993). Cultural Influences on National Rates of Innovation. *Journal of Business Venturing*, 8: 59-73.

- Shefer, D., & Frenkel, A. (2005). R&D, Firm Size and Innovation: An Empirical Analysis. *Technovation*, 25(1), 25-32.
- Smelser, N.J., & Swedberg, R. (2005). *The Handbook of Economic Sociology*. Princeton University Press, Princeton.
- So, J. (1987). Some Empirical Evidence on the Outliers and the Non-Normal Distribution and its Uses in Fitting Data. *Journal of Business, Finance & Accounting*, 14(2), 483-496.
- Symeonidis, G. (1996). *Innovation, firm size and market structure*. OECD, Paris.
- Taylor, M.Z., & Wilson, S. (2012). Does culture still matter? The effects of individualism on national innovation rates. *Journal of Business Venturing*, 27(2), 234-247.
- Tellis, G.J., Prabhu, J.C., & Chandy, R.K. (2009). Radical innovation across nations: The preeminence of corporate culture. *Journal of Marketing*, 73(1), 3-23.
- Tiwari, A.K., Mohnen, P., Palm, F.C., & van der Loef, S.S. (2007). *Financial constraints and R&D investments: Evidence from CIS*. UNU-MERIT Working Paper, 2007-011.
- Ugur, M., Trushin, E., Solomon, E., & Guidi, F. (2016). R&D and productivity in OECD firms and industries: A hierarchical meta-regression analysis. *Research Policy*, K(10), 2069-2086.
- Ulijn, J., & Weggeman, M. (2001). Towards an Innovation Culture: What are its National, Corporate, Marketing and Engineering Aspects. Some Experimental Evidence. In J. Cooper, S. Cartwright, & P.C. Early (Eds.) *The International Handbook of Organizational Culture and Climate* (pp. 487-517). Wiley & Sons.
- Van Oostrom, M., & Fernández-Esquinas, M. (2017). Exploring the links between culture and innovation in micro firms: Cultural dimensions, social mechanisms and outcomes. *European Planning Studies*, K(11), 1932-1953.
- Walker, G., & Weber, D. (1984). A Transaction Cost Approach to Make-or-Buy Decisions. *Administrative Science Quarterly*, 29(3), 373-391.
- Wang, S., Guidice, R.M., Tansky, J.W., & Wang, Z.M. (2010). When R&D spending is not enough: The critical role of culture when you really want to innovate. *Human Resource Management*, 49(4), 767-792.
- Wiersema, M.F., & Bantel, K.A. (1992). Top Management Team Demography and Corporate Strategic Change. *Academy of Management Journal*, 35(1), 91-121.
- Westwood, R., & Low, D.R. (2003). The Multicultural Muse. Culture, Creativity and Innovation. *International Journal of Cross Cultural Management*, 3(2), 235-259.
- Yalcinkaya, G. (2008). A culture-based approach to understanding the adoption and diffusion of new products across countries. *International Marketing Review*, 25(2), 202-214.
- Yukl, G. (1999). An evaluative essay on current conceptions of effective leadership. *European Journal of Work and Organizational Psychology*, 8: 33-48.
- Zelizer, V.A. (2010). *Economic lives: How culture shapes the economy*. Princeton University Press, New Jersey.
- Ziegler, A., and Nogareda, J.S. (2009). Environmental Management Systems and Technological Environmental Innovations: Exploring the Causal Relationship. *Research Policy*, 38(5), 885-893.