Revista Española de Documentación Científica
45(1), enero-marzo 2022, e319
ISSN-L:0210-0614. https://doi.org/10.3989/redc.2022.1.1832

ESTUDIOS / *RESEARCH STUDIES*

Business engagement with science: Opening the black box of perception of science in the business sector

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Recibido: 08-09-20; 2ª versión: 11-12-20; Aceptado: 14-02-21; Publicado: 31-01-2022

Cómo citar este artículo/Citation: López-Navarro, I.; Tabernero, C.; Rey-Rocha, J. (2022). Business engagement with science: Opening the black box of perception of science in the business sector. *Revista Española de Documentación Científica*, 45 (1), e319. https://doi.org/ 10.3989/redc.2022.1.1832

Abstract: Industry has reached a prominent role in recent European scientific policies, related to a shift in the production model towards an intensive knowledge-based economy. In spite of that, an understanding of business engagement with science is still deficient. The aim of this study was to test the relation between firm managers' perceptions of science and business engagement in research and development in their companies. This research is based on the results of the Scientific Culture at Enterprises 2016 survey, the first research tool specifically designed to investigate science perception in the business sector. Results show that what distinguishes a firm that is proactive toward R&D engagement is primarily the institutional knowledge of its managers about the scientific ecosystem and the variety of scientific sources they habitually consult. This research contributes to opening the black box of science perception in the business sector, focused on improving the design of public policies addressed to this actor.

Keywords: perception of science; business; survey; R&D; engagement with science.

El compromiso del sector privado con la ciencia: abriendo la caja negra de la percepción de la ciencia en la empresa

Resumen: La industria ha desempeñado un papel relevante en las recientes políticas científicas europeas. Sin embargo, el conocimiento de la relación entre ciencia y empresa es aun deficiente. El objetivo de este estudio es comprobar la relación entre la percepción de la ciencia de los directivos y la propensión (o no) a desarrollar proyectos de investigación en sus empresas. Este trabajo está basado en los resultados de la encuesta *Cultura Científica Empresarial 2016*, la primera realizada específicamente para estudiar la percepción de la ciencia en el sector empresarial. Los resultados muestran que las empresas proactivas en I+D se distinguen, principalmente, por el conocimiento institucional de sus directivos acerca del ecosistema científico y la variedad de fuentes de información científica consultadas. Este estudio contribuye a abrir la "caja negra" de la percepción de la ciencia en el sector empresarial, con el fin de mejorar el diseño de las políticas públicas dirigidas a este actor.

Palabras clave: percepción de la ciencia; empresa; encuesta; I+D; compromiso con la ciencia.

1. INTRODUCTION

In the last decades, the Public Understanding of Science (PUS) approach has faced the challenge of responding to an increasing number of questions regarding the relationship between science and society. One of the underlying concerns in this area has been to elucidate which variables encourage public engagement in science. In order to resolve this question, PUS surveys have become a useful and habitual tool since they were first implemented in the late 1970s (see Bauer, 2009 for a revision). These types of instruments have provided empirical material of great value to test main PUS hypotheses, to check the relationship between different perception variables, to make comparisons between public engagement in different countries and to put the data in context with other types of contextual indicators (Durant et al., 1989; Godin and Gingras, 2000; Bauer and Durant, 1999; Shukla, 2005; Allum et al., 2008; Bauer et al., 2012; Guenther et al., 2018). However, it is also true that they still suffer from certain deficiencies, such as a lack of periodicity, of a body of comparable questions, and of theoretical support for some of the measuring instruments (Bauer et al., 2007).

Most of these approaches have been dedicated to analysing public perception of science in the general population, emphasising in some cases their differences, for example, by age, gender or nationality. However, with notable exceptions (Prpić, 2011, for example) there are hardly any studies that focus on key sectors of modern societies, such as the political, judicial, financial or business classes. Therefore, the question is: Why should we limit the target of PUS studies only to the general public? Why not expand focus to agents, as business managers, who are in fact largely involved in the execution of research and the appropriation and transfer of scientific knowledge. Recently, Bauer (2014) pointed out the need to continue expanding the framework 'to reveal the diverse relations that different sections of the modern public have with science'. In this research, we propose to approach the understanding and perception of science by one of these key audiences, the business sector, traditionally neglected in the PUS field.

A brief review of the canonical journal in this area, *Public Understanding of Science*, shows a symptomatic fact: between 1992 and 2019, none of their published articles included the words 'industry', 'firm', 'company' or 'business' among their keywords —In fact, the first article in *Public Understanding of Science* with 'industry' as a keyword was published during the writing of this paper, in October 2019—. Despite this, there are some articles in the journal in which companies appear as a main or secondary actor in the paper. However, when this happens, they usually appear in relation to their role in scientific controversies that concern public opinion, such as genetically modified organisms (GMOs), climate change, biotechnology or chemical pollution. That is, there is a clear bias in the PUS literature—and Science, Technology and Society (STS) literature in general—that usually relates the business sector with a special ability to 'manufacture doubt' about science when it threatens their corporate and special interests (Stocking and Holstein, 2009). Not surprisingly, the Science and the Public report (OST and Wellcome Trust, 2001) revealed that there is a negative perception of the power of industry to set the scientific agenda along with certain concerns about the preservation of the scientific arena from corporate interests.

However, this gap in the literature contrasts with a growing role of industry in the European scientific policies related to a shift in the production model towards an intensive knowledge-based economy (Saisana and Munda, 2008). In fact, since the detection of the so-called 'European-Paradox' (European Commission, 1995) —the conjecture that EU countries play a leading global role in terms of scientific output, but lag behind in the ability of converting this strength into innovations (Dosi et al., 2006)— concern about the relation between research and innovation is increasing (Frenz and Ietto-Gillies, 2009). In this scenario, a large volume of data about the inputs and outcomes produced by the relationship between science and business is available: that is, how much money they invest in research and development (R&D), how many research projects they execute, how many patents they register, how many doctors they hire, etc. —see, for example, the collection of the Science and Technology Database of Eurostat (Eurostat, 2020)—. Nevertheless, the relationship of company managers with science remains black boxed. We still have a theorical and empirical gap about which type of perception variables could influence the implementation of pro-scientific behaviours in companies. This study aims to open that 'black box' on the premise that the imagery about science and technology that an individual harbours depends on —or rather is mediated by— the social role and position that he/she occupies (Godin and Gingras, 2000; Sturgis and Allum, 2004).

Gonçalves et al. (1996) and Prpić (2011) showed their surprise about the scarce surveys of perceptions of science conducted among business managers and other power elites who have a possible influence on scientific and technological policies. But little has been done since then to resolve this gap, although Prpić showed that managers reveal views about science and its implications that are significantly different from those of the wider public. In general, elites express 'a remarkably lower level of traditionalism', and they are 'more inclined to idealize science' than is the general population (2011). In the same year, López-Navarro et al. (2011) also confirmed that, in the Spanish context, the perception of science in the wider public and among entrepreneurs and self-employed workers was significantly different, particularly regarding institutional trust and risk management

In a recent work, we found that the image of science in the business sector is shaped by 'entrepreneurs' and business managers' perception of science, their interest in and knowledge of science and technology, and their willingness to take action regarding science, R&D and innovation' (Rey Rocha et al., 2019). We thus propose that business engagement in R&D is related to entrepreneurs' and managers' perception of science. Particularly, the aim of this study was to test this relationship and to measure the effect that certain PUS variables have on it.

With respect to these direct research antecedents, we have considerably expanded the number of dimensions included in our survey and the targeted sample, including companies of all economic sectors and sizes. Finally, our study not only describes business sector perception of science, but attempts to provide empirical evidence about its relationship with R&D execution.

This research is based on the results of the Scientific Culture at Enterprises 2016 survey (Rey-Rocha and López-Navarro, 2016), the first research tool specifically designed to investigate science perception in the business sector. We have included, on the one hand, classic dimensions traditionally used in most science perception surveys, which count on a considerable volume of previous literature and a high consensus about its implementation: namely, knowledge, attitude, interest and information. On the other hand, less usual dimensions -related to the recent 'science and society' paradigm (Bauer et al., 2007)- have also been included: institutional trust, closeness and appropriation.

The following is a review, which is not intended to be exhaustive, about the main consensus and vanishing points in relation to the use of each of these variables in the PUS field. The methodology used for this work is presented, followed by the main results of our research. Finally, the capabilities and limitations of the perception of science variables to explain research engagement in the business sector and their implications related to science policy are discussed.

2. LITERATURE REVIEW

Previous literature has speculated about what is scientific culture when we talk about the business sector. For example, Godin and Gingras (2000) pointed out that 'for industrial executives and managers, it could be the capacity to invest wisely in research, and to evaluate and select from a group of new technologies, as well as to provide for adequate employee training and proper equipment maintenance'. Elzinga and Jamison (1995) pointed out the relevance of the cultural dimension of scientific policy, including the bureaucratic, academic, civic and economic cultures, in their conceptual typology. The economic culture or approach to scientific policy was typical of industrial companies and it was focused on the technological appropriation of science and a more accounting perspective of R&D. In the theoretical approach to innovation adopted by Quintanilla (2004), the propensity to engage in R&D is related not only with the economic capability of the firm to do so but also to its attitude toward science and technology.

However, in spite of theoretical approaches, little is known in the empirical field about the perception of science in companies. Prpić (2011) used the above-mentioned typology proposed by Elzinga and Jamison (1995) to investigate the perception of science of different key social actors. She showed that managers´ views of science were less traditional and more optimistic than of the wider public. However, a gap has been found in the literature review about the relation between perception of science and appropriation of science in the business sector. In contrast, we have a huge empirical baggage if we talk about the general public instead of business managers or entrepreneurs. Therefore, it is convenient to review the results of the use of the main variables of the PUS approach in order to transfer them into an empirical model that explains the relationship between perception of science and business engagement in R&D activities. In our review, we attend to the PUS traditional variables of knowledge, attitude, interest and information and a secondary group of variables with a more recent presence in the public perception of science surveys and that also have a certain empirical and conceptual relevance.

PUS traditional variables

As in other scientific fields, the PUS approach is not exempt from theoretical and methodological debates arising from their different 'tribes' (Bauer et al., 2007), which have been clarifying their positions over the years. In this non-linear trajectory that has spanned more than 30 years, there are issues that have almost permanently hoarded academic interest and issues that have modulated their presence according to the different Science, Technology and Society (STS) academic approaches.

In the field of Science Perception Studies, it is possible to identify a set of variables that we could call 'classic' or 'traditional' and for which continuity can be traced since the emergence of the PUS field. The seminal studies of the National Science Foundation (NSF) introduced their already traditional triad composed of interest, knowledge and attitude as central elements of the public perception of science. In general, the main authors who carried out the first analyses on the social perception of science in the 1980s did so based mostly on a cognitive dimension in which knowledge played a central role in shaping attitudes towards science (Miller, 1983; Thomas and Durant, 1987; Durant et al., 1989).

A fruitful debate was subsequently opened on the distinction between different types of knowledge and the particular effect that each type has on the formation of scientific culture. Specifically, the proposals revolved around two types of knowledge: facts and methods. Facts related to textbook knowledge and methods to the scientific method (Miller, 1983). In the 1990s, the relationship between knowledge and attitudes became the focus of research (Einsiedel, 1994; Evans and Durant, 1995). However, the hypothesis about the deficit model was declared as inconclusive due to lack of empirical correlation (Bauer et al. 2007; Brossard and Lewenstein, 2009; Miller, 2004; Simis et al., 2016), and the validity of traditional ways of measuring knowledge was questioned (Pardo and Calvo, 2004; Sturgis and Allum, 2004).

Some proposals were presented to refine and broaden the definition of scientific knowledge and its different typologies. In this sense, Miller (1998) added to his initial proposal a third type of knowledge —civic scientific literacy— defined as the knowledge about the repercussions that science could have on society. In the same vein, Bauer et al. (2000) introduced the category of institutional knowledge of science —that is, knowledge about the institutional framework of scientific production—, which is related to the autonomy of scientists and the way in which scientific institutions function. These new approaches led to reformulations and qualifications that have allowed a better understanding of the role that knowledge plays in the shaping of scientific attitudes. For example, Sturgis and Allum (2004) defended the central role of knowledge in attitudes towards science but ruled out that it is a linear relationship. In their work, they introduced the concept of political knowledge as a type of 'political sophistication', demonstrating that this type of knowledge has a modulating effect on the shaping of attitudes. Allum et al. (2008) pointed out that the correlation depends largely on the type of knowledge that is being discussed. In addition, they showed that, when it comes to knowledge related to a scientific controversy that affects citizenship, the correlation between knowledge and attitude decreases or even disappears. Recently, Simis et al. (2016) claimed that individuals do not interpret information only in a rational and objective manner; hence, we cannot talk only about one type of public in science communication. In the process of appropriation of knowledge, particular relations remain underexplored.

Other works gave prominence to the dimension of the interest in science as the main factor that influences the formation of knowledge and attitudes (Durant et al., 1989). Takahashi and Tandoc (2016) 'show that interest in science not only directly predicts knowledge but also has indirect effects on knowledge through its effects on Internet use, confidence in the press, and perception of scientists'. The Science and the Public report (OST and Welcome Trust, 2001) showed a positive relationship between interest and the possible benefit of research topics: the greater perceived benefit among the public, the greater the degree of public interest.

In recent years, the study of attitudes towards science and technology has been expanding its scheme. At first, it was focused exclusively on two possible responses to scientific advances: confidence in its benefits or distrust of its risks. This led to unsuitable measures and a very rough classification of citizens in function of a polarised scheme (Cámara et al., 2017). Recent studies have shown that individuals with a high degree of knowledge and interest in science do not have monolithic attitudes but are able to discriminate the benefits and harms based on the type of specific scientific progress about which the questionnaire is asking (Miller, 2004; Bauer, 2009; Cámara et al., 2017). Likewise, the Science and the Public report (OST and Wellcome Trust, 2001, 329) proposed a new approach, suggesting that 'attitudes toward life influence attitudes toward science'; that is to say, it is not possible to continue analysing this *niche* of attitudes towards science as a watertight compartment. It would be more appropriate to interpret it as a little star within the complex constellation of the cultural and political system (Godin and Gingras, 2000; Sturgis and Allum, 2004; Bauer et al., 2007; Sinn, 2019).

The informative dimension is situated outside, but always very close, to the traditional triad of knowledge, interest and attitude. This variable has received attention in recent years, especially from the science communication approach, and Bauer et al. (2007) have suggested that the role of the mass media will be of vital importance to expand the PUS agenda in the coming years. Information is closely related to interest and attitudes, and it is somewhat correlated with public support for science funding (Qin and Brown, 2007; Ho et al., 2010 and 2011; Sanz-Menéndez et al., 2014). However, Besley (2018) pointed out that it became an insignificant predictor once put into a multivariate context.

Third generation PUS variables

In recent years, the number of studies on the perception of science has increased considerably. Consequently, it has led to an increase in the diversity of indicators in addition to the previously mentioned 'traditional variables'. Although there is a certain methodological consensus in maintaining a corpus of traditional indicators in periodic surveys, sporadic research has explored other dimensions. This second type of variable suffers, for now, from more limited empirical evidence and a lack of consensus regarding its measurement. However, its relevance lies in the need for 'more complex conceptual and/or methodological approaches to provide a deeper insight into the relation between science and the public' (Prpić, 2011, 734). In this study, we called them *third generation* variables in reference to the third and last paradigm —Science and Society— pointed out by Bauer et al., (2007) in their notorious revision of the trajectory of the PUS area. Institutional confidence, social appropriation of science and closeness to science are the most paradigmatic examples of this type of indicators.

These dimensions have to do with a relatively recent concern in the PUS field for trying to abandon an excessively cognitive approach in favour of trying to get closer to the dimension of the action (or at least predisposition to the action) and the context in which it is produced (Wynne, 1993; Wynne and Irwin, 1996; Sorensen et al., 2000). For example, the number of studies that ask about funding support, public participation or predisposition towards certain 'pro-scientific' behaviours has increased in recent years (López-Cerezo and Cámara, 2007; Besley, 2018). It could be said that, in the turn from the 'science literacy' paradigm to the 'public engagement' approach, this discipline has expanded its interest, not only to understand what is happening inside the minds of the citizens in relation to science but to their effective behaviour regarding this issue.

All of the aforementioned studies have led to an exploration of a more political and practical vision of the relationship between science and society based on 'its central role in economic development, public policy and personal life' in democratic societies (López-Cerezo and Cámara, 2007).

Framed in this turn, appropriation refers to the inclination to use scientific knowledge in decisions that affect everyday life situations, either individually or collectively (Godin and Gingras, 2000; Cámara-Hurtado and López-Cerezo, 2012). Although the empirical evidence about this dimension is still limited, one of the main consensuses is that appropriation cannot be explained entirely by prior knowledge or individual interest in science, nor does it reflect a linear relationship with these variables (López-Cerezo and Cámara, 2007). This approach, in which appropriation is understood as a process of acquisition of scientific culture in a broader sense, would be strongly mediated by the socio-political characteristics of the context in which it occurs (Sorensen et al., 2003).

The role of the institutions related to scientific production are part of this context. Therefore, public confidence in them constitutes another issue of relevance in recent approaches (Bauer et al., 2007). While it is an issue that is very related to some classic variables -especially institutional knowledge (Bauer et al., 2000)- its novelty lies in the contextualist turn: science is always produced and consumed in certain social and cultural conditions (Wynne, 2001), and confidence in the institutions that make up this context can mediate the way in which scientific information is received or even predispose the public towards more or less pro-scientific behaviours.

In modern societies, risk has taken on such an important role in the configuration of the collective imagination (Beck, 1992). Public trust becomes a key resource of the wider public in the allocation of institutional credibility when risk is derived from scientific or political decisions (Wynne, 1992). Increasing complexity in the relations between science and society has led to a growing dependence on experts that sometimes forces citizens to make leaps of faith (Möllering, 2006). In this context, mediated by a sense of loss of control, the public could consider that, in general, regulation -institutionalised distrust- and the possible interference of the private sector is needed in a highly competitive research context characterised by pressures from funding as well as from the career structure and rewards system of science (Bates et al., 2010). Dierkes and Von Grote (2005) pointed out that confidence and socially situated attitudes play a role that is at least comparable to that of cognitive apprehension.

Sanz-Menéndez et al., (2014) identified the positive vision of scientific institutions as one of the variables involved in shaping favourable attitudes towards public spending on R&D. Fernández-Esquinas and Iturrate-Meras (2015) found a possible contradiction between the wide confidence towards organisms that execute science and technology, such as universities or public research centres, and the suspicions about the institutions that finance them.

Finally, closeness to science is the dimension that has less trajectory among third generation PUS variables, notwithstanding that a similar notion has already appeared in the 'Science and Technology in the European Community' Eurobarometer (European Commission, 1977). Although it has received different labels (i.e., cultural distance, proximity to science and technology) and has been measured in different ways (see, for example, BBVA Foundation, 2012 and European Commission, 2013), we decided to include this dimension in our study because it reflects a recurring and traceable concern in the PUS field, despite the fact that it has not been treated systematically enough.

Raza and Singh (2012) conceptualised the notion of *cultural distance* as the 'relative distance between scientific structures of configuring reality and peoples' cultural worldviews'. According to these authors, this gap could provoke a cultural distance between science and the public. Raza et al. (1997) had already warned that this distance can influence the difficulty in assimilating certain complex natural phenomenon, but it does not have to imply a decrease in the public's confidence in the explanations given by the scientific community. In a subsequent research, Raza et al. (2002) showed how the proximity to science, measured by the number of years of scientific schooling, could exert a relevant influence in the mitigation of the aforementioned cultural distance between science and the public.

In the last years, other approaches to measure the proximity or closeness to science have appeared. The International Study on Scientific Culture (BBVA Foundation, 2012) defined the proximity to science as an aggregate measure constructed from the level of monitoring of scientific information, the performance of other activities to obtain information on these topics and the link with the scientific career. In the Eurobarometer about Research and Responsible Innovation (European Commission, 2013), two questions were introduced for the first time in this type of survey, aimed at measuring the proximity to science and technology through personal and family scientific background. This dimension showed a correlation between choosing a scientific career and having an interest in, and feeling informed about, developments in science and technology. In this study, the question about closeness to science was inspired by social distance scales (Bogardus, 1933), as they were considered 'an indicator of cognitive and cultural distance between respondents at companies and scientists' (Rey-Rocha et al., 2019).

3. OBJECTIVE AND HYPOTHESIS

The main aim of this study was to test the relation between perception of science and R&D engagement in the business sector. We consider R&D engagement, as suggested by Godin and Gingras (2000), as a feature of scientific culture of the company, as a form of appropriation of science. Considering the aforementioned, we hypothesise that this form of appropriation —measured by the decision to carry out R&D activities in the company— should be positively related to the perception of science held by firm managers. In this sense, it would be predictable that not only traditional variables (such as knowledge, attitude, information and interest) contribute to explain R&D engagement but also that third generation variables (such as appropriation, closeness to science and institutional confidence) play a role in this relation. Our second objective in this study was to assess the weight of each one of the variables in their relationship with R&D engagement.

Finally, we have to consider previous contributions from other academic fields, especially the economic and innovation management area. This area has been providing empirical evidence for decades on the influence of economic and market structure variables on business research activity (Den Hertog, 1993; Van Dijk et al., 1997; Lee, 2003; Máñez et al., 2015; Doloreux et al., 2016). In the same way, the PUS field has shown the certain influence of individual characteristics, such as gender or age, on the public perception of science (Evans and Durant, 1995; OST and Wellcome Trust, 2001; Noy and O'Brien, 2019). For that reason, we decided to check our hypothesis controlling for individual characteristics of CEOs and structural and economic characteristics of the company.

4. MATERIAL AND METHODS

A detailed description of the methodology used in this research has been published elsewhere (Rey-Rocha et al., 2019; González-Bravo et al., 2020). However, to facilitate the comprehension of the present article, the most relevant aspects of our method and data analysis are summarized below.

Research instrument, population and sample

This research is based on the results of the *Scientific culture, perception and attitudes toward science and innovation in the Spanish business sector survey* (shortened to *Scientific Culture at Enterprises, SCe*), which was distributed to a representative sample of the universe of Spanish companies, stratified by size (number of employees) and activity sector.

The specially designed SCe questionnaire (Rey-Rocha and López-Navarro, 2016) seeks to elicit the opinions, attitudes, motivations, expectations and images towards science, R&D and innovation among entrepreneurs and company managers.

The questionnaire was administered by computer-aided telephone interviews to a sample of informants consisting of people with management responsibilities in companies, selected through segmentation by activity sector and company size, i.e., the number of employees. This method of administration involves some disadvantages and advantages (Block and Erskine, 2012; Cea D´Ancona, 1996). We found several significant benefits in using this method for our study object. Phone-based interviewing provides higher accessibility and reduce the effort involved in conducting fieldwork to a sample distributed in a wide spatial range: it allows accessing individuals who may not otherwise be available due to their location, or their agenda. In comparison with mail or email contact, phone-based surveying increases success in contacting eligible members of the target population. This was especially relevant since we were aware about the difficulty of getting a personal interview in a collective with changing busy agendas and that may be highly reluctant to questionnaires that imply an excessive cost of time. For these reasons, phone surveys may reduce refusal rates. On the other hand, trained interviewers

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

Population						
Sector	**Size (Number of employees)**					
	Micro <10	**Small 10-49**	**Medium 50-249**	**Large ≥250**	**Total number of companies**	
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	± 9.8%
Industry	100	53	27	22	202	± 6.9%
Energy	34	24	21	22	101	± 9.6%
Construction	37	24	20	20	101	± 9.7%
Services	118	40	23	22	203	± 6.9%
Total number of companies	325	165	111	106	707	± 3.7%
Margin of error	±5.4%	±7.7%	±9.2%	±9.4%	±3.7%	
Weighted sample						
Sector	**Size (Number of employees)**					
	Micro <10	**Small 10-49**	**Medium 50-249**	**Large ≥250**	**Total**	
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	

can ask the questions to the responded in a uniform manner, and provide them some help in understanding the content of questions.

Target informants ranged from people in management positions at large companies with substantial R&D activity, to entrepreneurs or representatives of microenterprises that in some cases are far removed from R&D. Selected informants include company owners and persons holding a CEO, company director or equivalent position (66% of the sample). In larger companies and in those cases where it was impossible to interview the head of the company, we interviewed alternative managerial positions with special relation with finance, innovation, R&D, production or technical departments, such as financial directors, technical directors, production directors or R&D directors (32.2%).

The original population consisted on 451,181 active Spanish firms with full economic, activity sector, number of employees, turnover and contact telephone data, in the Iberian Balance Sheet Analysis System (SABI database, Sistema de Análisis de Balances Ibéricos in Spanish). The selection resolves the excessive specificity of the samples used in prior studies on the business sector (Doloreux et al., 2016; Máñez et al., 2015).

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 ±3.7%, for a 95% confidence level. The original population, the distribution of the final sample by activity sector and company size are shown in Table I 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 weighted sample is also shown in Table I.

Study variables

Study variables were constructed from the selected survey questions displayed in Tables II and III, along with their basic descriptive statistics. Firm engagement in R&D activities constituted the explained variable (Table II). This variable involved the answers provided by the surveyed entrepreneurs and company managers 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. Explanatory variables reflect the conceptual framework exposed in the literature review (Table III). In this sense, we have a set of traditional PUS variables and a set of the so-called third generation PUS variables. The first group includes knowledge, attitude, interest and information. Knowledge indicators include institutional knowledge of science and the level of formal education of the respondents (measured as a proxy of knowledge of science), following Bauer et al., (2000) contribution. The second group is formed by institutional confidence, closeness to science and appropriation.

Control variables

Existing evidence shows that a firm's characteristics and industrial structure matter for expenditure and engagement in R&D (Arvanitis and Woerter, 2014; Davies 2011; Groot et al., 2011; Shefer and Frenkel, 2005). On the other hand, as a high-investment-cost activity, R&D requires firms to have the necessary resources. For these reasons, we additionally included three firm- and industrial-level

Table II. Explained variable

Variable	Description Survey question	% responses	
Engagement in R&D	The firm has engaged in some form of R&D (either internal, external or collaborative) (Q17.1 OR Q17.2 OR Q17.3)	1=Yes 38.3	0=Otherwise 61.7
	Q17. In the last 5 years (2011-2015), has your company carried out any of the following activities?		
	Q17.1. Intramural research or R&D (i.e., within the company)		
	Q17.2. Acquisition of extramural research or R&D (i.e., carried out by other public or private organisations)		
	Q17.3. Collaborative research or R&D (i.e., carried out jointly with other public or private organisations)		

Table III. Explanatory variables

Variable	Description Survey question	Values
Traditional variables		
Institutional knowledge of science	Knowledge of R&D institutions *Q7. Do you remember the name of any institution dedicated to scientific and technological research in our country?*	Yes / No: 41.0% / 59.0%
Level of formal education	Highest level of formal education *Q27. What is the highest level of formal education you have completed?*	No university degree/ Bachelor degree / Master and PhD degree: 43.2% / 41.1% / 15.7%
Attitude towards science	Positive attitude towards science index (Average Q11.1, 7, 9)	Average (Std. dev.): 3.4 (0.7)
	Q11. 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.	1=Don't agree / 2=Slightly / 3=Somewhat / 4=Strongly / 5=Fully agree / Don't know+No answer
	Q11.1. Scientists should play a more important role in business	1.3 / 2.9 / 16.9 / 30.1 / 48.6 / 0.22
	Q11.7. Science and technology can solve any type of business or production problem	12.1 / 20.8 / 39.3 / 20.9 / 6.5 / 0.4
	Q11.9. Scientific knowledge is the best basis for making business decisions	7.2 / 15.8 / 41.5 / 23.8 / 11.2 / 0.6
Interest in science and technology	Interest in advances in S&T applied to own's sector *Q 12. To what extent do you feel interested in advances in science and technology applied to your sector?*	Average (Std. dev.): 3.9 (1.1) 1=Not interested at all / =Slightly / 3=Somewhat / 4=Very / 5=Extremely interested / Don't know+No answer 5.7 / 5.5 / 17.6 / 32.4 / 38.3 /0.6
Use of scientific information sources	Number of scientific sources used by managers in their company: sum Q14.3, 4, 5, 11, 13)	Average (Std. dev.): 1.0 (1.3)
	Q 13. Do you regularly seek information to keep up to date about science and technology in your company?	Yes 71.2% (Go to Q14) / No 28.8%
	Q 14. Now I'm going to read a series of information sources about science and technology for your company. Please indicate which of these do you use habitually.	
	Q14.3. Commercial laboratories or private R&D institutes:	16.7%
	Q14.4. University and public research bodies	34.1%
	Q14.5. Informal conversations with researchers	44.5%
	Q14.11. Patent and industrial property offices	12.1%
	Q14.13. Technological centres	34.6%
Third generation PUS variables		
Institutional confidence	Surveyed individuals' degree of confidence in scientific institutions when addressing issues related to science and technology (Average Q16.2, 3, 7)	Average (Std. dev.): 3.8 (0.8)
	Q 16. Now I will list some institutions. I would like you to tell me the degree of confidence you have in each of them when addressing issues in your company related to science and technology.	1=No confidence / 2=Little / 3= Some / 4=Considerable / 5= Great confidence / Don't know+No answer
	Q16.2. Universities	2.0% / 5.0% / 20.7% / 38.4% / 32.8% / 1.1%
	Q16.3. Public research bodies	4.6% / 10.3% / 28.5% / 35.2% / 18.8% / 2.5%
	Q16.7. Spanish Council for Scientific Research	1.7% / 3.8% / 24.8% / 33.0% / 32.7% / 4.1%
Closeness to science	Level of closeness those surveyed would like to have with a scientist in a professional context	Average (Std. dev.): 3.1 (1.0)

Variable	Description Survey question	Values
	Q23. Now I'm going to read you several options. Please tell me what kind of relationship you would like to have with a scientist involved in research on topics related to your sector.	
	1=I would be interested if he/she could develop his/her professional work within my company	8.5%
	2=I would be interested in formally collaborating with him/her through an agreement between his/her institution and my company	28.2%
	3=I would be interested in occasionally knowing his/her opinion about some specific issues related to my sector	42.7%
	4=I would be interested in talking with him/her as a matter of personal curiosity, but not on professional issues	11.7%
	5=I would not be particularly interested in interacting with him/her for professional or for personal reasons	9.0%
Appropriation of science	Propensity to make professional decisions based on principles related to the experimental method and the use of scientific knowledge (Average Q24.1, 2)	Average (Std. dev.): 3.4 (1.1)
	Q24. Next I will read you a list of different actions when making an important decision regarding your company. Please tell me if they are behaviours you engage in.	1=Never / 2=Rarely / 3=Sometimes / 4=Quite often / 5=Always / Don't know+No answer
	Q24.1. I imagine different scenarios or try different options, and check what happens in each of them	8.6 / 6.9 / 27.5 / 25.9 / 29.6 / 1.5
	Q24.2. I seek updated information based on scientific knowledge	13.3 / 11.9 / 21.7 / 30.0 / 21.8 / 1.3

Table IV. Control variables

Variable	Description	Values
Company size	Number of employees	Fewer than 10 employees: 80.0% 10 to 49 employees: 16.8% 50 to 249 employees: 2.6% More than 250: 0.6%
Sector	Dummies based on the sector aggregation of the CNAE and NACE (*)	Agriculture (primary sector): 3.4% Industry: 13.1% Energy: 0.7% Construction: 13.4% Services: 69.4%
Return on assets (ROA) zROA: Typified by sector. Ordinal 1 to 5 (quintiles)	Earnings before interest and tax/ Total Assets	Mean (Std. dev.) 0.02 (0.01)
Age of respondents		Mean (Std. dev.) 46.3 (9.3)
Sex of respondents		Male: 68% Female: 32%

(*) The Spain's National Classification of Economic Activities (CNAE) and EU classification of economic activities (NACE) (INE, 2009). Sector aggregation: Agriculture (primary sector) (including CNAE sections A and B); Industry (Section C); Energy (Sections D and E); Construction (Section F); Services (sections G to U)

variables potentially related to a company's decision to engage in R&D: a) company size, b) activity sector, and c) the economic variable of return on assets (ROA), which is linked to firm ability to generate resources and its profitability, and is a variable commonly used in microeconomic business studies as an indicator of firm capability to generate income (Table IV).

The variable ROA showed a distribution with a long right tail. In order to avoid the size effect and resolve this asymmetry, this variable was typified to relativise each firm's value to the average in its sector, and then transformed into an ordinal variable with five categories based on quintiles of the original variable. The surveyed companies' economic data for 2014 were obtained from the SABI database.

Activity sector was obtained from a sector aggregation of the CNAE (the Spanish acronym for Spain's National Classification of Economic Activities) and the EU classification of economic activities (NACE) (INE, 2009): Agriculture (primary sector), industry, energy, construction, and services (see Table IV).

Individual characteristics of respondents (sex and age) were also included as control variables.

5. ANALYSIS

Our analysis approach consisted of logit regression models made to gradually add different variables to each of them to test their effect on R&D engagement. This step-by-step approach allows us to understand a) the sole effect of science perception variables (innovative and traditional); b) the added effect of individual control variables; and c) the added effect of structural and economic control variables.

The coefficients obtained for explanatory variables with suitable levels of significance estimate their relationship with R&D engagement in the business sector. Expβ coefficients above 1 indicate that an increase in the explanatory variable is related to an increase in the likelihood of a firm performing R&D activities (Table V).

Statistical analyses were done with the Statistical Package for Social Sciences (SPSS) v. 25.

6. RESULTS

A summary of the results for the regression models is provided in Table V, and the details of each analysis are shown in the Appendix. Model 1 includes perception variables, thus showing the probability of engaging in R&D in relation to the firms' perception of science. Models 2 and 3 incorporate the interaction terms to test the moderation effects involving individual characteristics of respondents and firm-level variables, respec-

Table V. Summary of the regression models (explained variable: Engagement in R&D)

Variables	**Categories**	**Model 1**	**Model 2**	**Model 3**
		β (odds ratio increases %)		
Level of formal education	No university degree (benchmark)			
	Bachelor degree	0.239 (27.0)	0.241 (27.2)	0.264 (29.2)
	Master and PhD degree	0.228 (25.6)	0.303 (35.3)	0.261 (28.0)
Institutional knowledge		1.063*** (189.5)	1.061*** (189.0)	1.067*** (192.3)
Attitude towards science		-0.286 (-24.8)	-0.305 (-26.3)	-0.261 (-23.0)
Interest in science and technology		0.500***(64.8)	0.480*** (61.6)	0.558*** (73.1)
Use of scientific information resources		0.843***(132.2)	0.844*** (132.5)	0.783*** (120.0)
Confidence in scientific institutions		-0.351 (-30.0)	-0.354* (-29.8)	-0.341* (-29.7)
Closeness to science		0.623*** (86.4)	0.702*** (101.8)	0.680*** (97.9)
Appropriation of science		-0.035 (-3.4)	-0.079 (-7.6)	-0.052 (3.4)
Age			0.025* (2.5)	0.023 (2.3)
Gender	Male (benchmark)		-0.059 (-6.0)	-0.039 (-5.9)
zROA 2014				0.228* (26.0)
Sector	Agriculture (primary sector) (benchmark)			
	Industry			0.126 (13.1)
	Energy			0.509 (66.9)
	Construction			0.799 (129.4)
	Services			-0.109 (-11.1)
Company size	Micro <10 (benchmark)			
	Small 10-49			0.804** (120.5)
	Medium 50-249			0.975 (170.7)
	Large ≥250			1.407 (320.8)
Constant		-3.611 (-97.3)	-4.705 (-99.0)	-4.517 (-99.5)
R^2		0.511	0.518	0.541

tively. The models accurately explain a relatively large proportion of variance in the explained variables (Nagelkerke R^2 values between 0.511 and 0.541). The insertion of control variables in the model barely generated changes in R^2 and in the significance and direction of the effect of science perception variables in the model.

The results show that institutional knowledge —that is, the capacity of CEOs to recognise scientific institutions in their environment—, together with the regular use of scientific institutions as information sources to keep up to date about science and technology in the company, are the variables that present the highest predictive capacity in the model (they show the highest beta coefficients, thus the highest odds ratio increases). When a company's CEO knows at least one scientific institution, the probability of he/she belonging to a company engaging in R&D activities increases by almost 200%. For every additional source of scientific information used, the probability of engaging in R&D activities increases by more than 100%. Interest in science and technology, and the level of closeness to science, are also significantly and positively related to business engagement in R&D. The level of confidence in scientific institutions is also significant but in an inverse direction. That is, the lower the confidence expressed by the managers of a company in scientific institutions when it comes to dealing with their company's issues related to science and technology, the more likely it is that the company will carry out R&D.

Models 2 and 3 show that the relationship between engagement in R&D and perception of science remains even after controlling for individual characteristics of the entrepreneurs and business managers and for economic and structural characteristics of the firms. Both firm capabilities to generate resources internally (ROA) and a certain firm size (above 10 employees) are positively related with R&D engagement; they also nullify the effect of the age of respondents when individual but not firm characteristics are considered.

7. DISCUSSION AND CONCLUSIONS

The results reported here confirm the potential we had already anticipated (Rey-Rocha et al., 2019; González-Bravo et al., 2020) of the Public Understanding of Science approach to light up issues related to scientific culture, not only in the general population but also in new scenarios such as the business sector.

The results of the first survey on scientific culture, perception and attitudes towards science and innovation in the business sector provide empirical evidence of a significant association of PUS variables and business engagement in R&D activities. A mix of traditional (institutional knowledge, interest, information) and third generation PUS variables (institutional confidence and closeness level) are significantly related with research decisions of the company, even when individual characteristics of business managers and economic and structural characteristics of firms are controlled.

The institutional knowledge of respondents about science and research systems, and the use of scientific sources of information were the variables more strongly associated with firms engaging in R&D activities. This result points to the relevance of the connection between the business sector and the innovation system, through an appropriate knowledge of research institutions by managers, to foster firm engagement in R&D activities. In other words, it suggests the importance of institutional and contextual knowledge —more than formal contents of scientific knowledge— when it comes to promoting engagement in R&D in the business sector. In fact, we found in our previous research that knowledge of scientific institutions was a better predictor of knowledge of science by CEOs than their level of formal education (Rey-Rocha et al., 2019). This contextual or institutional knowledge is related to the notion of tacit knowledge (Collins, 2010), a type of 'expert' and 'focused knowledge' that does not refer to the *corpus* of scientific knowledge itself but to the social and institutional system in which scientific knowledge is inserted as well as its management model. Familiarity with the institutional framework of science is thus essential for a closer approach to research by companies. Unfortunately, this type of knowledge has the particularity of being very difficult to transfer due because it is difficult to codify. This fact makes this 'institutional know-how' very dependent on the concrete person who holds the management position in the company/who the R&D decisions in the company. Like any other ability, this knowledge is not likely to be written or verbalised. For this reason, this type of skill usually goes with the manager when he/she leaves the firm or changes his/her position in the firm, revealing the volatile nature of this knowledge. In the light of the results obtained, it would be worthwhile to pay more attention to institutional knowledge in future analyses, as its inclusion in national perception of science surveys, or even in innovation studies, is still deficient.

The information dimension is closely related to institutional knowledge since the use of scientific sources of information implies certain previous knowledge about the organisations that produce it. This dimension has received increasing attention in PUS studies. Science communication, and the conditions under which it is produced, plays an increasing role in public engagement of science (Vraga and Bode, 2017; Bolsen et al., 2019). Our study confirms that, in the same way, the information dimension also makes an important contribution to explain business engagement in R&D.

Confidence in scientific institutions when addressing issues in the company related to science and technology is also significantly associated with R&D engagement but, surprisingly, in an inverse direction. This type of relation could suggest a kind of system failure related to the lack of confidence among innovative companies regarding the performance of universities and public research institutions. Our results show that intensive R&D companies were the most suspicious. That is, distrust would be related to their experience with this type of environment, not to the lack of contact with it. This result is consistent with previous work about cross sector collaboration and the distrust that generates public administration in the business sector (Diaz-Catalan et al., 2019) In fact, the Spanish business sector has traditionally developed their R&D internally and firms prefer this option over externalisation or collaboration with academic agents to obtain new knowledge (Industry, Economy and Competitiveness Ministry, 2017).

An inverse relation between institutional confidence and R&D engagement would also be interpreted as the reverse of one STS insight: 'distance lends enchantment' in science (Collins, 1985, 145). In this case, proximity to science —indeed, to scientific institutions— could lend certain criticism or distrust among the business sector. This interpretation is also in accordance with recent findings about the public perception of science in the general public carried out by Cámara et al. (2017). They identified 'critical engagers' as a segment of the population that holds an overall positive attitude towards science but is not reticent about expressing concern regarding particular scientific applications. The authors interpreted this result as a sign of a mature and conscious society, far from naïve positions towards the effects of science and technology applications. In the same way, our results suggest the existence of business as critical engagers; that is, firms that engage in R&D but are not reticent about expressing concerns about public research institutions.

Previous economic and innovation literature about the propensity of companies to carry on R&D activities very rarely has seen this disposition as a part of their scientific culture or, at least, as a form of scientific appropriation. With some exceptions (see, for example, Alam et al., 2019; Lorca and de Andrés, 2019), these academic approaches usually looked at market and economic variables to find the reasons that would explain R&D intensity (i.e., size of the company, economic sector, internal resources, debt, etc.) (Xu and Sim, 2018). For that reason, control variables have a particularly relevant role in this study, and their estimations/coefficients led us to confirm that all science perception variables remain necessary to explain R&D engagement in the business sector. Moreover, the explanatory power of the model does not substantially improve with the inclusion of structural and economic variables. However, results show that, on the one hand, engagement in R&D is positively associated with a firm's capability for generating income and, on the other hand, a minimum size is required to address these types of activities. Regarding demographic control variables, neither sex nor gender has a significant association with science engagement in firms when all variables are included in the model. This result is consistent with PUS literature on science funding support. If we understand R&D investment in the business sector as a similar phenomenon as science funding support in the general public, the recent work of Besley (2018, 97) has pointed out that previous literature only found 'limited relationships between demographics and support after controlling for more proximate variables'. In the same way, Prpić (2011) found that managers´ perception of science did not vary according to their gender. Only significant, yet small, differences were found in older respondents who tend to be more sceptical about science.

In 2007, Bauer et al. mapped the path of the PUS approach since its inception and anticipated 'a fertile period for survey research on public understanding of science (…) albeit within the wider framework of science and society' (2007, 79). The present study, inspired in the proposal mentioned by Bauer, et al. (2007), formulate a cross fertilisation between the studies on business innovation and innovation management and the public understanding of the science approach. That is, a new actor for a consolidated —and revisited— academic approach.

The relevance of the inclusion of new actors lies in the idea that, not only were there many publics (Einsiediel, 2000) but also multiple perceptions of science, bearing in mind that each perception is mediated by the social role of individuals and groups (Godin and Gingras, 2000). The particular position that the business sector has in the society —closely related to knowledge generation and transfer, appropriation of science and science and technology policies— could contribute to complete the complex puzzle of collective S&T culture (Rey-Rocha et al., 2019).

Finally, situated in the business scenario, the PUS approach has the potential to pose new answers —based on science perception indicators— to old unresolved questions related to business innovation and R&D in order to generate more accurate S&T policies. That is, the incursion into this new scenario positions the PUS approach in a strategic place to address the challenge of improving the relationship between science and the business sector. Our results confirm that the PUS approach is a valid interlocutor, among many others, to talk about R&D engagement: what distinguishes a firm that is proactive toward R&D engagement is primarily the institutional knowledge of its managers about the scientific ecosystem in which the company is inserted and the variety of scientific sources they habitually consult. When we put PUS variables in the equation, money also matters but in a modest way (see also González Bravo et al., 2020).

Turney (1996, 1087) stated that 'we need to improve the scientist's understanding of the public'. Today, maybe we could apply this recommendation to point out that not only managers and CEOs should have a better understanding of and engagement with science, but academics and science policy makers must have a better knowledge of the business sector as a particular public. In summary, PUS studies need to expand their agenda (Bauer et al., 2007) since they have the capacity to light up certain dark areas that the economy or innovation studies cannot solve alone when it comes to dealing with business engagement with science.

Further research is also needed to counteract the limitations of the present study. Due to questionnaire limitations, the knowledge variable could not be measured in a direct manner, so we had to use level of formal education as a proxy for this dimension. In future research, it is recommended to include in the survey a specific question for this purpose. Second, the economic indicator used as a control variable leaves out more specific indicators, such as leverage of the firm or asset turnover, that could refine our results. Third, it would ideally be recommendable that this study could open a new line of research in which more specific studies —centred in a particular sector or business size— could be replicated and compared with this general sample. This would allow us to test whether the relations found in this study vary in particular contexts.

It is particularly important to note that the cross-sectional nature of our data constrains the possibility of testing causal links between PUS variables and R&D engagement. We have been especially careful in the paper not to impute this type of relation in the interpretation of our results. Future research is also needed for a better explanation of the relation among variables. As López-Cerezo and Cámara-Hurtado (2007) proposed, the relation among science perception variables should be understood as a 'non-linear process of a gradual, reciprocal and recursive character'. This would give us a better understanding. of the function of the behaviour of these types of variables and it would avoid the temptation to fall into linear interpretations.

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 their engagement in R&D. The results provide sundry openings for further research to reinforce them. Some of the perception dimensions invite further and more detailed study, through different quantitative and qualitative research approaches and instruments.

Confidence and trust are particularly important in relationships of companies with science, scientists and scientific institutions. They invite further research, which should investigate factors as attribution of scientific institutions' effectiveness when dealing with particular problems for the company.

Finally, in regard to our explained variable, it would be interesting to distinguish between the three more common categories included in R&D (internal, external and collaboration) in order to prove whether particular perception variables change its direction or its intensity. In the same way, in addition to R&D engagement, engagement in innovation activities must be investigated as explained variables in this line of research.

8. ACKNOWLEDGEMENTS

We acknowledge help from José Manuel Rojo, Francisco Javier Campón and Yasmina González, from the Statistical Analysis Unit at the Centre for Human and Social Sciences (CCHS-CSIC). 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. We thank Maria Isabel González Bravo (University of Salamanca) for her advice with the economic variables. We thank Proof Reading Service for revising the English translation of the manuscript.

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

8. AGRADECIMIENTOS

Agradecemos la ayuda de José Manuel Rojo, Francisco Javier Campón y Yasmina González, de la Unidad de Análisis Estadístico del Centro de Ciencias Humanas y Sociales (CCHS-CSIC). Expresamos nuestro reconocimiento a Aitor Vallejo, Nagore Fernández y el equipo de la empresa Quor por la colaboración en el diseño de la muestra y la encuesta telefónica, así como a todos los participantes del estudio por haber hecho posible este trabajo. También agradecemos a Maria Isabel González Bravo (Universidad de Salamanca) su consejo en el diseño de las variables económicas. Por último, mostramos nuestro reconocimiento a Proof Reading Service por la revisión de la traducción del manuscrito.

Este trabajo ha sido financiado por el Ministerio de Economía, Industria y Competitividad [CSO2014-53293-R] y la Fundación Española para la Ciencia y la Tecnología (FECYT) [FCT-16-10889].

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). Rights: Open Access. Identifier: http://hdl.handle.net/10261/223009.

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APPENDIX. LOGIT REGRESSION MODELS

Table VI: Regression model summary (Model 1)

Variables	Categories	β	Standard Error	Wald	Sig.	Exp (β)	Percent increase odds (%)
Level of formal education	No university degree (benchmark)			1.175	0.556		
	Bachelor degree	0.239	0.229	1.090	0.296	1.270	27.0
	Master and PhD degree	0.228	0.324	0.493	0.483	1.256	25.6
Institutional knowledge		1.063	0.217	23.909	0.000	2.895	189.5
Attitude towards science		-0.286	0.156	3.352	0.067	0.752	-24.8
Interest in science and technology		0.500	0.124	16.202	0.000	1.648	64.8
Use of scientific information resources		0.843	0.101	68.934	0.000	2.322	132.2
Confidence in scientific institutions		-0.356	0.139	6.539	0.011	0.700	-30.0
Closeness to science		0.623	0.128	23.516	0.000	1.864	86.4
Appropriation of science		-0.035	0.116	0.091	0.763	0.966	-3.4
Constant		-3.611	0.836	18.660	0.000	0.027	-97.3
R2	0.511						

Table VII: Regression model summary (Model 2)

Variables	Categories	β	Standard Error	Wald	Sig.	Exp (β)	Percent increase odds (%)
Level of formal education	No university degree (benchmark)			1.327	0.515		
	Bachelor degree	0.241	0.234	1.064	0.302	1.273	27.3
	Master and PhD degree	0.303	0.334	0.823	0.364	1.354	35.4
Institutional knowledge		1.061	0.222	22.858	0.000	2.890	189
Attitude towards science		-0.305	0.158	3.704	0.054	0.737	-26.3
Interest in science and technology		0.480	0.127	14.373	0.000	1.616	61.6
Use of scientific information resources		0.844	0.102	67.771	0.000	2.325	132.5
Confidence in scientific institutions		-0.354	0.142	6.219	0.013	0.702	-29.8
Closeness to science		0.702	0.134	27.494	0.000	2.018	101.8
Appropriation of science		-0.079	0.117	0.454	0.500	0.924	-7.6
Age		0.025	0.012	4.291	0.038	1.025	2.5
Gender	Male (benchmark)	-0.059	0.242	0.059	0.808	0.943	-6.0
Constant		-4.705	0.986	22.753	0.000	0.009	-99.0
R2	0.518						

Table VIII: Regression model summary (Model 3)

Variables	Categories	β	Standard Error	Wald	Sig.	Exp (β)	Percent increase odds (%)
Level of formal education	No university degree (benchmark)			1.203	0.548		
	Bachelor degree	0.256	0.242	1.122	0.289	1.292	29.2
	Master and PhD degree	0.247	0.345	0.514	0.473	1.280	28.0
Institutional knowledge		1.073	0.228	22.107	0.000	2.924	192.4
Attitude towards science		-0.262	0.163	2.592	0.107	0.769	-23.1
Interest in science and technology		0.548	0.134	16.723	0.000	1.731	73.1
Use of scientific information resources		0.788	0.105	56.117	0.000	2.200	120.0
Confidence in scientific institutions		-0.351	0.147	5.693	0.017	0.704	-29.6
Closeness to science		0.683	0.138	24.553	0.000	1.979	97.9
Appropriation of science		-0.041	0.121	0.114	0.735	0.960	-4.0
Age		0.023	0.012	3.485	0.062	1.023	2.3
Gender	Male (benchmark)	-0.061	0.244	0.062	0.804	0.941	-5.9
zROA 2014		0.231	0.114	4.068	0.044	1.260	26.0
Sector	Agriculture (primary sector) (benchmark)			3.217	0.522		
	Industry	0.123	0.559	0.049	0.826	1.131	13.1
	Energy	0.512	0.329	2.419	0.120	1.669	66.9
	Construction	0.830	1.248	0.442	0.506	2.294	129.4
	Services	-0.117	0.332	0.125	0.724	0.889	-11.1
Company size	Micro <10 (benchmark)			10.124	0.018		
	Small 10-49	0.791	0.280	7.999	0.005	2.205	120.5
	Medium 50-249	0.996	0.699	2.031	0.154	2.707	170.7
	Large ≥250	1.437	1.503	0.914	0.339	4.208	320.8
Constant		-5.342	1.042	26.288	0.000	0.005	-99.5
R2	0.541						

Rev. Esp. Doc. Cient., 45(1), enero-marzo 2022, e319. ISSN-L: 0210-0614. https://doi.org/10.3989/redc.2022.1.1832