Exploring the Image of Science in the Business Sector: Surveying and Modeling Scientific Culture, Perception and Attitudes towards Science

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Abstract

The 'Scientific Culture at Enterprises' (SCe) project aims to identify the different factors that characterize the image of science held by entrepreneurs and business managers, explore the relationships among these factors, and shed light on the role they play in defining this image and ultimately in developing a culture of science in the business sector. This article is based on the results of the SCe 2016 survey with a specially designed telephone survey questionnaire of a representative sample of Spanish companies. The novelty of our approach lies in the application of a model developed in the fields of Social Studies of Science and Public Understanding of Science to the business sector, in order to obtain information on the dispositions of perception, interest, knowledge and action and their relationships with science and innovation in the business sector in Spain. Using the PIKA model of the image of science**,** we found this image in the business sector to be 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. Implications for the public perception and understanding of science are discussed.

Keywords: scientific culture; image of science; business

Introduction

The science–business gap and the lack of scientific and innovative culture in the business landscape

The business sector has become increasingly important in public Science and Technology (S&T) policies and plans, in light of its special links to progress towards change in production models based on the knowledge economy (Fernandez Zubieta et al. 2015; OECD 2015). This fact contrasts, in practice, with scenarios in which a so-called 'gap between research and market' has been identified. This phenomenon is defined by a lack of business participation in the financing and execution of research and development (R&D) and innovation – particularly the absence of cooperation with the public sector – and by the lack of strategies for the identification, assimilation and exploitation by companies of the knowledge generated by universities and public research centers (European Commission 1995, 2011; Leydesdorff, Cooke, and Olazarán 2002; UNESCO 2015).

The causes leading to this situation have traditionally been attributed to economic or managerial variables (Van Dierdonck, Debackere, and Engelen 1990; Liyanage and Mitchell 1994; Bayona, García-Marco, and Huerta 2001, 2002). In recent years, other views have been considered that go beyond strictly economistic thinking (Cooke and Morgan 1998; Sanz and Cruz 2005; D'Este and Iammarino 2010; Fernández-Esquinas and Ramos 2011). The results of these efforts highlight the need to study the link between science and business as a social relationship, taking into account not only institutional and contextual factors, but also the cultural and subjective factors that operate in organizations, and the individuals involved in this relationship.

In Spain in particular, the gap between research and business has been associated with a weak culture of science and innovation in the business sector (Castro

García and Fernández de Lucio 2006; Cotec 2014). This weakness was openly recognized in the Spanish Strategy for Science and Technology and Innovation 2013-2020 report and the National Plan for Scientific and Technical Research and Innovation 2013-2016 (MINECO 2013a, 2013b).

In this connection, the 'Scientific Culture at Enterprises' (SCe) project originated from the assumption that the perception of and attitudes toward science and innovation, and ultimately, the scientific culture of companies and their image of science, can have a decisive influence on key behaviors related to their R&D activities. Among the objectives of the SCe project are a) to develop a research tool for gathering information from companies and analyzing scientific and innovative culture in the business sector, and, b) to develop a suitable model that can contribute to a better understanding of the image of science in the business sector. Our aims were thus to identify the different dimensions or factors that make up this image, to explore the relationships among them, and to elucidate the role they play in defining this image and ultimately in the development of a culture of science and innovation within companies.

Culture is a property of groups, and hence is a defining feature of organizations. The concept of culture is applied to organizations within a given society to explain different patterns of behavior and levels of stability among groups and organizations, on the understanding that features of the “global” culture within a society is not sufficient to explain these differences (Schein 1985).

At any level we consider, culture is a multidimensional concept. Within organizational culture the innovation dimension has attracted substantial interest (e.g. Anderson and West 1998; Dobni 2008), but studies published thus far have devoted little attention to the scientific dimension. The present study is intended to help fill this gap.

Approaching the problem from a Social Studies of Science perspective

In recent decades different authors have repeatedly pointed out the need to strengthen our scientific insights into the public understanding of science to better understand citizens' relationship with science (Lèvy-Leblond 1992; Lewenstein 1992; Miller 1992; Macintyre 1995; Wynne 2014). Along similar lines, we argue here that there is a need to improve our scientific understanding of the business sector, in order to better understand its relationship with S&T, R&D and innovation, and how scientific knowledge is built, used, validated and transferred in the collective business landscape. However, analyses carried out in the fields of Social Studies of Science (SSS) and Public Understanding of Science (PUS) have systematically neglected the business sector, and focused mainly on the general population or specific citizen groups delineated by gender, age or nationality.

Consequently our first task was to develop a questionnaire to explore scientific culture, perceptions and attitudes towards science and innovation in the business sector, for which we relied on methodological tools and previous research in SSS and PUS. This instrument was later used in a survey of a representative sample of companies in the Spanish productive sector. In light of the results of this survey, the main aim of this research is to analyze the factors that contribute to the image of science, R&D and innovation in the business sector.

The novelty of our approach lies in the application, for the first time, of methods and tools from the fields of SSS and PUS to the business sector – specifically, our efforts to elucidate its relationships with science, R&D and innovation. We believe that this approach can shed light on hitherto occluded aspects of this relationship, by going beyond strictly economistic thinking and ultimately improving our understanding of the gap between science and business.

The need for a theoretical framework and a conceptual model

The evolution of discourse in the field of PUS across the paradigms of Scientific Literacy, PUS, and Science and Society has been described by different authors (Bauer, Allum, and Miller 2007; Laspra 2014). In this ‘multiplication of discourses’ (Bauer 2009, 222), three broad categories of analysis and indicators have emerged: a) knowledge indicators, developed mainly within the framework of the ‘scientific literacy’ paradigm; b) interest indicators; and c) attitude indicators, particularly relevant in the context of the PUS paradigm. This set of dimensions of the culture of science – i.e. the epistemic dimension (knowledge) and the attitudinal or evaluative dimension (beliefs and attitudes) – is complemented by the behavioral dimension. i.e., what individuals do with what they know, and with their beliefs and attitudes (Cámara-Hurtado and López-Cerezo 2012).

The lack of a theoretical framework is considered a relevant constraining factor in research on the relationships between science and society, PUS, and public perception of science (Pardo and Calvo 2002; Bauer, Allum, and Miller 2007). In this connection, Muñoz van den Eynde, Laspra, and Díaz García (2017) discussed the problems in the field derived from circular thinking and the reproduction of outdated models, e.g. the deficit model, which is still propounded by some despite criticisms.

In an attempt to develop a model that provides a conceptualization which complements the operationalization used to obtain a reliable survey instrument, we relied on the Perception, Interest, Knowledge, and willingness to Act (PIKA) model of the image of science developed by Muñoz van den Eynde, Laspra, and Díaz García (2017).

The PIKA model describes,

> 'the interaction between the citizens perception of science (P), their interest on the issue (I), their knowledge (K), and the disposition to act (A) regarding science, assuming that the image of science is running in the background when individuals act and make decisions in their everyday life'. (Muñoz van den Eynde, Laspra, and Díaz García 2017, 3)

The model relies on the work of the neurologist Antonio Damasio (2010) and describes the image of science from a naturalistic approach:

> 'when we talk about the image of science we are not referring to a picture, but to the mental representation every citizen build [sic] as a result of his or her knowledge and experience with science. It also includes what they feel regarding science as a result of their interaction with it in their daily life'. (Muñoz van den Eynde, Laspra, and Díaz García 2017, 4)

In words of the PIKA model proponents:

> 'this model acknowledges that by interacting with science in their social environment, people generate an image of science in their mind that determines how they react to it. This image depends on knowledge, perception, and interest. In turn, interest and knowledge have a direct influence on the disposition to act regarding science'. (Muñoz van den Eynde, Laspra, and Díaz García 2017, 17)

In consonance with the storyline proposed by the PIKA authors (2017, 4), we postulate that both entrepreneurs and business managers shape an image of science, R&D and innovation as a result of their interaction with them in their daily professional life within a specific social environment. Simultaneously, their social environment influences this image as a result of the relationship between business, on one hand, and science and scientific knowledge, on the other hand. Decision making and strategic choices in companies – such as those made in order to manage R&D engagement and innovation – are determined to a great extent by the characteristics and functioning, as well as the values, knowledge and beliefs held by decision-makers and managers (Bantel and Jackson 1989; Wiersema and Bantel 1992; Mezghanni 2010). In addition, their decisions are guided by cultural and social factors that also influence their image of science. With this in mind, and in accordance with Hambrick and Mason's (1984) upper-echelons perspective, we consider management staff to be representative of a firms' perception and attitudes towards science.

Considering the aforementioned, the present study focuses on companies as decision units and on the perception and attitude towards science of companies' decision-making agents in their role of representatives**.** These actors, besides constituting an aggregation of individual motives and interests, are embedded in complex social macrostructures, as postulated by the social economy and the New Institutionalism paradigm (Powell and Colyvas 2008; Zelizer 2010). Within these structures certain institutional values, traits, rules, norms and needs operate (Meyer and Rowan 1977; Hitlin and Piliavin 2004). For instance, these actors are embedded not only in the culture of their activity sector, but ultimately in the culture of their company. This cultural and regulatory system, operating at the macro, meso or micro level, influences (or even determines) norms and beliefs held by firms and individuals; therefore it may favor certain attitudes towards science, R&D and innovation, and obviate or even penalize others.

Finally, we chose the PIKA model for various reasons. First, we are interested in understanding scientific culture in the business sector from the perspective of the PUS and SSS fields, and the PIKA model provides a bottom-up approach – from data to theory – that helps overcome some of the limitations that have emerged in the field in recent years (Muñoz van den Eynde, Laspra, and Díaz García 2017). Second, the PIKA model attributes a preponderant role to the behavioral dimension. This is a key feature of this model for our purposes, considering that, as noted above, we are interested in further analyzing the influence of the scientific culture of companies on key behaviors related to their innovative and R&D activities. Third, although the article by Muñoz van den Eynde and colleagues focused on individuals' image of science, the authors recognized the relevance and influence of the social environment; this is what makes the PIKA model potentially applicable to the study of enterprises (or other social groups).

Undoubtedly, the model does not address other relevant social constructs such as values, which are "a potentially propitious arena in which to examine the reciprocal influence between social structural positions and individual functioning and decision making" (Hitlin and Piliavin 2004, 383). But given the complexity of the image of science, efforts to unravel the factors that contribute to and thus shape it should be addressed step by step. Moreover, components of the PIKA model constitute the factors that are usually included in surveys of the public perception of science (Pardo and Calvo 2002).

Hypothesis and objectives

From a theoretical perspective, this research is grounded on the assumption that perceptions and attitudes of entrepreneurs and company managers, and their image of science, can influence and even determine the scientific culture of a company. At the same time, the social environment influences entrepreneurs' and managers' image of science as a result of the relationship between business, on one hand, and science and scientific knowledge, on the other. In line with the assumptions of the PIKA model about citizens' relationships with science, and in accordance with New Institutionalism postulates, our approach assumes that the relationship of businesses with science, R&D and innovation depends on and simultaneously determines the image the business sector holds about these concepts. Our assumption here is that research will benefit from the identification of factors that shape the image of science in the business sector, through insights gained from multivariate data analyses.

Therefore, our hypothesis was that the image of science held by entrepreneurs and company managers is influenced by perception, interest, knowledge and disposition to act regarding science, R&D and innovation, assuming that the image of science is 'running in the background' when individuals and companies make decisions and act in their everyday business life.

The aim of this study was to test whether the PIKA model of the image of science, developed to contribute to a better understanding of citizens' perspectives regarding the relationship between society and science, is an appropriate model to analyze and better understand the perspective of the business sector regarding its relationship with science.

In following this approach, the present study explores the image of science among entrepreneurs and company managers, as well as the representation of the corporate image by companies, understood as the mental representation our respondents build based on their knowledge and experience with science, and how they feel about science as a result of their interactions with them in their daily professional life.

Materials and methods

The research tool: The SCe questionnaire

This research is based on the results of the SCe 2016 survey, which was distributed to a representative sample of Spanish companies, stratified by size (number of employees) and activity sector. For this purpose, a specially designed questionnaire (Rey-Rocha, López-Navarro et al. 2016) was developed and administered by telephone, as described below.

Most empirical research on R&D and innovation in business has been grounded on the analysis of data regarding patents and licenses, the creation of academic spin-offs, etc., leaving aside the whole dimension of tacit knowledge indispensable for the development of innovation. The design and operationalization of the SCe questionnaire were guided by the aim of obtaining a tool to advance the acquisition of knowledge about and the understanding of ways in which business relates with science. Unlike questionnaires designed to address the perception of science by the general public, the SCe questionnaire was specifically intended to bring out opinions, attitudes, motivations, and expectations towards science, R&D and innovation among entrepreneurs and company managers.

The theoretical conceptualization and subsequent implementation of the information in the items that constitute the final questionnaire were based on a literature review of existing surveys and research, a set of pilot interviews with entrepreneurs and company managers, and discussions among members of the SCe multidisciplinary research team.

We opted for probabilistic sampling in order to obtain a representative picture of the Spanish business sector.[1] The need to obtain a representative sample, together with the requirements of a telephone survey, led us to design a questionnaire that was straightforward and not time-consuming to use, albeit with due attention to rigor in the

1 The advantages and drawbacks of using probabilistic samples versus convenience samples to allow more complex questionnaires to be designed were discussed by Hox (1997) and Muñoz van den Eynde, Laspra, and Díaz García (2017), among others.

choice of dimensions and topics, as well as to the subsequent operationalization of the items. During the design phase many items were operationalized with the aim of covering the different topics addressed. Although many of these items were not used in the 2016 survey, they constitute a collection that will make it possible to broaden and adapt the questionnaire to different contexts and fieldwork methodologies in the future.

The SCe survey is innovative in its objectives and the population it targeted. Furthermore, the questionnaire includes items dealing with 'classical' dimensions including knowledge, attitude and interest, and also incorporates the behavioral dimension through items asking about behavioral disposition, e.g. the willingness to make use of scientific knowledge and take actions regarding science, R&D and innovation.

Study variables

The PIKA model '*describes the segment that includes the interaction among four dispositions: Perception [which includes two products: attitudes and opinions], Interest, Knowledge and Action*' (Muñoz van den Eynde, Laspra, and Díaz García 2017, 4). The present study focuses on these four dispositions or constructs, which are considered here in the same sense as described by the PIKA creators. Each disposition was initially addressed through different indicators, operationalized in different SCe items (See Appendix). In this section we briefly describe each disposition, and refer the reader to the original paper by these authors (Muñoz van den Eynde, Laspra, and Díaz García 2017, 4-6) for a more complete description.

Perception

Perception is the cognitive process which involves processing scientific information from our environment and rebuilding it by assimilating it into our mental maps (Mather

2006; Damasio 2010). Indicators of the perception of science, R&D and innovation are operationalized in the SCe questionnaire through the following items:

Q5: Difficulty of doing R&D

This item explores the perception of the ease or difficulty for companies of doing R&D, and provides a basic indicator of the image or perception of the environment. Its formulation is based on a question from the 9th International Barometer on Innovation Funding 2013 (Alma cg 2014, 21), adapted to the field of R&D and the business sector.

Q6: Vision of science

This item probes the ideas that come to the respondent's mind when thinking of 'science'. It is formulated as in the PIKA questionnaire, but on a 5-point scale instead of a 9-point scale. Cronbach's alpha reliability coefficient for the responses to the eleven Q6 items (=.956, with .70 as the lowest acceptable value) indicates high internal consistency among the responses, which yields the indicator 'vision of science' as the sum of the responses to all items.

Q9: Balancing public effort in R&D

This item investigates preferences in the allocation of public funds to science versus other budget lines. Its original formulation in the PIKA survey was kept. It establishes a gradient between more essential and less essential budget items, and thus allows us to see where science is located. In evaluating the results, it is less important to determine the relative preferences for each specific item and more informative to see where science is located in general. In addition to providing an indicator of the valuation of public effort in R&D, it is also an indicator of the respondent's attitude toward science, the value of science and the importance attributed to it.

Q11: Role within business of S&T, R&D, scientific knowledge and scientists

This item explores issues related to control and independence (specifically, the need for control over R&D and researchers within companies), trust, expectations for S&T, as well as the role and relevance of scientific knowledge for decision making within companies and their willingness to use it. A low Cronbach's alpha coefficient indicated no internal consistency among items, so they were not summed into a unique indicator but instead were analyzed separately.

Q15: Benefits and risks for companies of investing in R&D

Respondents are asked to rate, on a scale of 1 to 5, their degree of agreement with a series of statements. Benefits/advantages and risks/disadvantages are contemplated separately, in order to avoid the drawbacks of treating them as a two-dimensional continuum (see Laspra 2014, 39). Cronbach's alpha was low, so no summed indicator was calculated. In view of the results, our strategy was to summarize separately responses to statements that reflected benefits or positive perceptions of investing in R&D (Q15.2, Q15.4, Q15.5 and Q15.7) and responses that reflected risks associated with R&D investment (Q15.1, Q15.3, Q15.6 & Q15.8). Cronbach's alpha for benefits was acceptable (.737), so a summed indicator was calculated. For items on risk perception, values of Cronbach's alpha were low, so they were analyzed separately.

Q16: Institutional confidence

This item analyses respondents' confidence in different institutions regarding S&T issues.

Q23: Relationship with scientists

This item was inspired by social distance scales (see for example Bogardus 1933; Dodd 1935), in which indirect questions are posed about the distance of the respondent from a specific group – in this case scientists. It can be considered an indicator of cognitive and cultural distance between respondents at companies and scientists, as well as an indicator of attitude toward scientific knowledge, relevance of knowledge, and willingness to use it.

Interest

Surveys on the perception of S&T in the general public usually focus on capturing citizens' information about S&T and interest in S&T issues. These surveys usually investigate interest through items about informative interest, general interest in science, and perceived level of information.

In the SCe questionnaire, apart from the item about interest associated with the idea of science generally (see Q6), two more items were used to investigate the interest disposition.

Q12: Interest

This item asks respondents not about their interest in S&T in general, but instead about their level of interest in advances in S&T applied to their business sector.

Q13: Information on S&T

This item investigates interest in S&T as reflected through actions taken to stay informed about S&T within the company. It focuses on discovering whether informants' usual practice is to seek information to keep up to date about S&T in their company as entrepreneurs or managers, rather than as citizens.

Knowledge

Measurements of scientific literacy have traditionally been structured as surveys of public perceptions around four dimensions (Bauer 2009): a) knowledge of basic theoretical constructs or scientific facts; b) understanding of scientific methods; c) appreciation of S&T results and outcomes; and d) rejection of superstitious beliefs. The SCe questionnaire did not include items on any of these dimensions. More recently, new dimensions have been considered, such as the institutional dimension of science, which includes knowledge of scientific institutions and the S&T system (Bauer, Petkova, and Boyadjieva 2000; Pardo Avellaneda 2014; RICYT 2015) and knowledge of scientific controversies (Bauer, Allum, and Miller 2007).

Q8: Knowledge of institutions dedicated to scientific and technological research.

Respondent were asked to name up to three different institutions they recalled. Only responses that correctly named the institution and referred to an institution or center actually dedicated to scientific and technological research were counted as correct responses denoting accurate knowledge.

Q10: Knowledge of public and private R&D effort.

This item investigates whether informants are aware of the distribution of R&D investment between public and private sectors.

Q27: Formal education, indicated by highest level of education completed.

Actions

Actions refer to whether people are in a position to put science and scientific knowledge into practice, or whether they play a role in shaping citizens' daily life and in their ability to make decisions and choose courses of action (López Cerezo and Cámara 2007; Muñoz van den Eynde, Laspra, and Díaz García 2017). Surveys are not able to measure actions, but only dispositions to act, that is, the willingness to do something. In this regard the SCe questionnaire was designed to detect whether science and scientific knowledge play a role in carrying out activities or dealing with problems within the company.

Q24: Knowledge-building and use in business

Statements in this item probe broad areas of behavior about epistemological[2] aspects of knowledge construction and use, particularly the manner in which scientific, critical knowledge informs decision making at companies. This item presents different courses of action when making an important decision regarding the company, and asks respondents to indicate the frequency with which they themselves engage in these behaviors. Cronbach's alpha was good (.82), so the 'knowledge-building and use in business' indicator was obtained by summing the responses to all five statements.

Q17: R&D and innovation activities

This item explores whether or not the respondent's company has carried out R&D and innovation activities in the last five years. In the analysis, intramural, extramural and collaborative R&D activities were summed into a single 'R&D activities' variable indicating whether or not the company carried out or invested in R&D. Variables Q17.4 and Q17.5 were analyzed separately.

The SCe 2016 survey. Population, sample and fieldwork

The 2016 SCe survey was administered 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. Computer-aided

2 'Epistemology addresses the ways in which knowledge claims in science are developed and justified, e.g. assessing the quality of data, the relationship between phenomena and theory, and how conflicts of ideas are resolved in science' (Ryder 2001).

telephone interviews were carried out from mid-September to mid-October 2016.

We have focused on the perception of science of decision makers within the company, i.e. entrepreneurs and managers. In business surveys, the company is usually considered the reporting entity, as is the organization in innovation surveys. These latter surveys thus pay little attention to the behaviors, points of view and traits of its members (Wang and Ahmed 2004, Dobni 2008, Tang 1999). Because SCe is a perception survey, the reporting body was the person who owns the company or who holds managerial responsibilities as a representative of the company, although the respondent also speaks for himself or herself when asked about personal issues or details.

The original population of active Spanish companies was obtained from the Iberian Balance Sheet Analysis System (SABI database, *Sistema de Análisis de Balances Ibéricos* in Spanish)[3]. As of December 2014, this database incorporated a total of 1,107,094 active companies, of which data on activity sector, number of employees, turnover and contact telephone number were available for 451,181. 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 (1.96 σ with respect to μ, for p=q=.5). The distribution of the final sample by activity sector and company size is shown in Table 1.

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3 Produced by eInforma [https://www.informa.es/en/financial-solutions/sabi].

[Table 1 near here]

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.

Analysis

As in Muñoz van den Eynde, Laspra, and Díaz García (2017), we tested the PIKA model through structural equation modeling (SEM). This statistical technique uses a confirmatory approach to analyze a structural theory about a given phenomenon. The hypothetical model can be tested statistically through simultaneous analysis of all variables to determine consistency of the model with the data. This approach aims to obtain estimates of the parameters in the model, i.e. the factor loadings, variances and covariances, and the residual error variances of the observed variables. The next step is to assess model fit, i.e. whether the model itself provides a good fit to the data (Hox and Bechger 1998; Byrne 2010). Structural equation modeling makes it possible to examine the relationships among the different indicators of key dimensions, and simultaneously to identify the model that optimizes them. For a more detailed explanation of the methodology used to test the PIKA model, we refer the reader to the paper by Muñoz van den Eynde, Laspra, and Díaz García (2017).

All analyses were done with SPSS version 22.0 and AMOS version 18.0.

Results

As in the study by Muñoz van den Eynde, Laspra, and Díaz García (2017), we found the image of science to be shaped by knowledge, interest, perception and the disposition to act regarding science, R&D and innovation. The SCe questionnaire included questions different from those in the *Fundación Española para la Ciencia y la Tecnología* (FECYT) and PIKA questionnaires; hence the model we obtained is not exactly the same as that reported from these surveys.

Basic descriptive statistics for the variables used in this study are shown in the Appendix. The final SEM measurement model tested with the SCe 2016 survey is shown in Figure 1.

Factor loadings showed that perceiving investment in R&D as beneficial for the company (Q15.Benefits factor loading = .85) was the best predictor of perception: in other words, perception was best defined by factors reflecting a positive perception of the benefits of R&D, and worse defined by factors reflecting its perceived risks. Perception was also defined by the belief that scientists should play a more important role in companies (Q11.1 factor loading = .47), the belief that scientific knowledge is the best basis for decision making (Q11.9 factor loading = .30), and by vision of science (Q6 factor loading = .44). Perception also correlated, but negatively, with the perception that investment in R&D is a waste of time for companies and that it is always more profitable to use the knowledge generated by others (Q15.6 factor loading = −.42). The opinion that scientific knowledge is the best basis for making business decisions (Q11.9 factor loading = .30) showed a weak association, but model fit worsened when this factor was removed, so we kept it in the model.

Two indicators measured the interest construct: feeling interested in and staying informed about S&T (Q12 and Q13, with factor loadings of .74 and .69, respectively). This indicated that interest in S&T within the business sector is defined not only by the explicit mention of interest by businesspeople and managers, but also by their proactive attitude toward staying informed about these issues.

Regarding indicators for the knowledge construct, the SCe survey only provided an opportunity to identify them as a function of level of education (Q27 factor loading = .54) and the knowledge of institutions dedicated to scientific and technological research (Q8 factor loading = .70). Knowledge was best defined by this last factor, and to a lesser extent by the level of formal education.

Both indicators used to measure action (Q17 and Q24) fit the model. Action related to science and scientific knowledge was best explained by the extent to which companies carry out or invest in R&D internally, externally and/or in collaboration (Q17. R&D activities factor loading = .80) and innovation activities (Q17.4 factor loading = .65). Factors that contributed less to action were managerial actions when making an important decision regarding the company (Q24 factor loading = .31).

The PIKA model predicts that knowledge helps to explain perception, interest and action related to S&T. It is important to recall here that in the SCe survey, knowledge about S&T is reflected through an indirect indicator (formal education) and mainly through knowledge of R&D institutions. Knowledge measured with these two variables helped to explain interest (covariance = .58) and action (.77) related to S&T, but contributed little to explain perception (.28). On the other hand, action correlated strongly with both interest (.71) and knowledge (.77).

From the measurement model we obtained a structural model (Figure 2), where we defined a second-order factor that represents the image of science in the business sector. According to our structural model, a segment of this image of science was defined by the relationships among the four constructs, i.e. perception, interest, knowledge and action. Model goodness of fit, as measured by comparative fit index and root mean square error of approximation, worsened slightly compared to the measurement model, although the structural model remained satisfactory.

Perception was the factor with the weakest explanatory loadings according to the survey results (only 18% of the variance), probably because this is the most complex disposition. Conversely, the image of science explained 65% of the variance in the interest construct, 63% of the variance in knowledge, and 83% of the variance in action.

[Figure 1 near here]

[Figure 2 near here]

Discussion

The aims of this study were to find an effective model to improve the understanding of the image of science in the business sector by identifying the factors that shape this image, and to explore the relationships among these factors.

Overall, entrepreneurs and business managers in Spain show a positive attitude towards R&D. They tend to associate science with positive ideas, and investment in R&D with benefits; they are also interested in advances in science and technology applied to their sector, and in the role of scientists as well as scientific and technological development within business. At the same time, they feel that R&D in Spain is difficult, appear not to be very knowledgeable about Spanish scientific institutions, and are under the misapprehension that most investment in R&D in Spain comes from the private sector. On the other hand, with regard to engagement in R&D, the results disclose a less promising reality: our respondents tend to be interested in occasional exchanges of opinion with scientists working in topics related to their company's particular sector, and to a lesser extent, in establishing formal agreements with external scientists, whereas only a minority are interested in employing scientists within their company.

Moreover, most enterprises in Spain have never tried intramural R&D, acquisition of extramural R&D, or collaborative R&D, nor have they purchased or licensed patents, utility models or industrial designs.

Our results provide arguments in favor of conferring a more prominent role to scientists within companies, and of using scientific knowledge in business decision making. Our findings also reflect a positive view within companies of the benefits of investing in R&D versus the risks, based on the perception that companies investing in R&D are likely to obtain long-term economic benefits, enjoy a competitive advantage, improve their image in the market, and create new jobs within the company. Investing in R&D was not perceived as a waste of time, and most businesspeople and managers did not consider it more profitable to use the knowledge generated by others.

Unlike the PIKA and FECYT surveys, the results of the SCe 2016 survey provide data that yield a good approximation to the definition of the action construct. Although actions cannot be objectively measured through a survey, we obtained a valid approximation by including items about action in the questionnaire. Action in relation to science, R&D and innovation is more easily measurable in companies than in the general public. In samples drawn from the general public it is challenging to elicit information about aspects other than respondents' willingness to act, whereas the SCe survey asked about R&D and innovation activities actually carried out by companies. The data obtained from respondents' answers – note that the empirical recording of these activities was not our objective – constituted a good indicator for characterizing these actions. Action related to science and scientific knowledge measured in the SCe survey is best explained by the extent to which a company actually carries out R&D and innovation, rather than by how entrepreneurs and business managers construct and use knowledge. Nevertheless, although knowledge building and use contributes less to the definition of the action construct, this factor was an accurate indicator of the behaviors aimed at using scientific and expert knowledge for decision making in the business sector.

As in the model tested with the FECYT and PIKA surveys, we found that knowledge is a key factor that influences the other factors considered here. Educational level, a nonspecific indicator, was a worse predictor of knowledge of science than our informants' knowledge of scientific institutions, regardless of their level of formal education. Thus we are speaking here of a specific category of knowledge – a type of 'expert' and 'focused knowledge'. Moreover, knowledge in business settings is defined more by institutional knowledge than by economic or financial knowledge regarding the source of funds. In other words, it is determined more by the knowledge of who participates than by the knowledge of who finances. In the 2016 SCe questionnaire we did not include indicators of scientific literacy, but it is worth highlighting here the importance of two factors: the educational level of entrepreneurs and managers, and more importantly, the evidence that our respondents had adequate knowledge of the institutions in their country that are dedicated to R&D. Although no further indicators of institutional knowledge were used in this initial survey (other than the general perception that it is difficult for companies to carry out R&D, although this factor did not fit the model well), this result indicates the relevance of having a better in-house knowledge of the R&D system and the possibilities it offers. Therefore, increasing entrepreneurs' and managers' educational level and particularly their institutional knowledge of the R&D system seem to be key traits, which can be complemented with the hiring of researchers and R&D managers by companies. Improvements in these areas may be desirable in the context of efforts to increase business engagement in

S&T, R&D and innovation, and to increase entrepreneurs' and managers' perception of the crucial importance for their companies of S&T, R&D and innovation.

As reflected by the results of the 2016 SCe survey, knowledge influences action to a greater extent than interest or perception. Knowledge contributed little to the factors that influence perception, indicating that there are other important factors to consider, most notably interest. The strong correlation between perception and interest supports the hypothesis that interest in science within businesses determines perception and ultimately behaviors (action or engagement) in R&D and innovation. In any case, the absence of significant correlations with variables that explain the opinion construct indicates that additional research will be needed to identify and characterize other influential factors.

The present study has implications for the public perception and understanding of science in general. In recent times the field of studies of the public understanding of science and technology has experienced relevant changes. From an academic perspective, a new paradigm has emerged that combines elements of both continuity with and divergence from the deficit model. At the institutional level, both research and technology policies as well as innovation strategies have been impacted by the crisis in linear models, leading to the current emphasis on interactions among R&D agents to achieve objectives. Public–private cooperation constitutes one of the fundamental axes of interaction among R&D agents. Nevertheless, despite the relevance of the business sector in this new model, it has been the focus of very little empirical research. Additionally, symbolic issues associated with science, such as values and attitudes, remain under-studied. We believe that one of the most innovative contributions of this article to the field of PUS research stems from the new knowledge it provides regarding entrepreneurs' and business managers' perceptions and attitudes toward science. The results and discussion reported here constitute an initial exploration of a research niche that opens broad perspectives for the study, analysis and reflection on scientific, technological and innovation culture.

This study draws on the paradigms and tools of PUS studies to contribute to the development of a conceptual model that can be used in the future to analyze factors related to research and innovation activity in the business sector. Such factors include not only the structural and economic characteristics of companies, but also social and cultural factors related with the perception and attitudes towards science of the actors involved, and ultimately with their image of science and, on a broader level, scientific culture.

Most perspectives on the implications and contributions of enterprises to R&D have neglected the influence of social and contextual variables of relevance in attempts to understand the relationship of business with science. The business sector perspective is surprisingly underrepresented in Science-Technology-Society (STS) studies. We believe our results contribute significantly to fill this gap by analyzing the science–business link as a social relationship. We grounded our analysis of this sector, which is little-studied despite being a key actor in science policy, on tools and conceptual models used in PUS studies. This field has traditionally focused on individuals, and has devoted less attention to groups and organizations as key determinants of the ways in which the public interacts with science. Our results exemplify the benefits of complementing the approach used in PUS studies focused on individuals with an analysis of the interactions of different groups with science. In this sense, our approach relies on the PIKA model and also takes into account social economy and neo-institutional postulates, as well as the postmodern approach – also called the constructivist, "interactive science" perspective (Wynne 1995; Einsiedel 2000), which considers the strong social and institutional embeddedness of economic actors and “the inseparability of science from its social and institutional contexts” (Einsiedel 2000, 205). Thus, although institutional-level effects are not analyzed here, we acknowledge that they underlie the responses to our survey. Our approach to the study of the image of science in the business sector is focused mainly on the cognitive and normative nature (Scott 2005) of beliefs, rules, roles, and symbolic elements of institutions, rather than on the regulative nature of businesses as institutions.

In addition, the present study highlights the differences that may arise when the perception, understanding, and more broadly the image and culture of science are analyzed in specific sectors of the population and in specific contexts, in comparison to the findings of studies designed to investigate the understanding and perception of science in the general public.

Although “the public” has been considered a homogeneous entity, in fact there is a plurality of publics (Dewey 1927; Einsiedel 2000). Different sectors of the population may have specific perceptions of science that depend on the context in which their views are solicited. Moreover, these perceptions may differ according to whether the respondents are approached as citizens or as actors within the environment in which their interactions with science take place, i.e. in a professional or employment context. It is thus clear that a given individual can belong to different publics.

This study also makes a valuable contribution to the PUS field by considering new variables and dimensions beyond the ones usually included in traditional surveys of the public perception of science and technology, which tend to focus on the classical dimensions of interest, attitude and information. Thus, for example, the cognitive and cultural distance of people from business with regard to scientists is a fairly novel indicator that we investigated with a question based on social distance scales. This response mode was chosen as the best available approach, in light of the lack of methodological precedents. These more innovative variables may not always fit well in the statistical analyses, so further discussion and empirical analyses are needed to improve our understanding of their role in explaining the image of science in the business sector. More specifically, future research could take these variables into account by considering indicators that can be readily adapted to specific contexts and populations.

Further research is also needed to counteract the limitations of the present study. Additional information can be obtained by testing different versions of the questionnaire, administered with different methods, in order to investigate their effectiveness in contributing to knowledge about scientific culture in the business sector. Furthermore, the data in this study were from a single country and thus may not be representative of the business sector in different countries or regions; therefore this study should be replicated in other populations.

In this study we analyzed the image of science in a sample of the entire Spanish business landscape, across all areas of activity. But one might ask whether this image is homogeneous or variable within businesses that share structural and contextual characteristics such as size and sector of activity. DiMaggio and Powell (1983), working within the framework of neo-institutional theory, argued that as organizational fields go through their life cycle stages and evolve to become highly structured, the institutional context obliges organizations to become more similar and more homogeneous – i.e. isomorphic – through coercive, mimetic and normative processes. This view raises the question as to whether entrepreneurs' and business managers' perceptions and attitudes toward science exhibit varying degrees of isomorphism within activity sectors or companies of a particular size. An alternative question, from the standpoint of early organizational theory, is whether there are degrees of heterogeneity and diversity within and across sectors and company sizes. These questions offer relevant areas for further research.

We are aware of the importance of organizational change. Further research could reveal variations in the image of science in the business sector, in response to social, institutional and political shifts that affect companies and their relationship with science – e.g. changes arising from the evolution of society and the economic environment, from the implementation of science and innovation policies, or from the scientific culture of society in general, among other factors. Future studies could thus shed light on organizational changes resulting, in the words of Meyer and Rowan (1977, 362), from "variations in the institutional structure of the wider environment" and "variations in organizational structure among societies, and within any society across time".

Furthermore, it should be recalled that the findings of the present study are derived from the institutional logic of entrepreneurs and managers, whose perceptions, as mentioned earlier, are a major driver of companies' corporate and scientific culture. We are nonetheless aware that the notion of institutional pluralism means that within companies, other institutional logics coexist that can contribute in different ways to shaping a company's image of science. A paradigmatic model for these coexisting logics might be that of small, technology-based companies, in which practically all staff take part in these contributions.

Alternatively, the question on how social actors may, purposively or not, influence their institutional context has been proposed as a promising avenue in the development of institutional theory, both from a theoretical perspective and in empirical research (Lawrence and Shadnam 2008). Therefore, in future research it would be interesting to determine whether staff members' image of science influences the organization's scientific culture, or whether it may make companies more likely to engage in R&D and innovation. These institutional phenomena invite further study, which should undoubtedly not only investigate exogenous factors but also seek possible endogenous explanations.

Depicting the image of science in businesses as a neural network was useful in this initial attempt to find a model able to explain the interactions between the business community and science, R&D and innovation. Nevertheless, to better understand these interactions, better indicators are needed for the factors that shape the image of science in the business sector. The model reported here is the best one tested thus far, in terms of goodness of fit, and allowed us to use the indicators in the SCe survey to reliably identify the four constructs in the PIKA model (e.g. perception, interest, knowledge and action) and their interrelationships. In any case it should be recalled that models are only approximations, and that a perfect fit to the data cannot realistically be expected (Hox and Bechger 1998). Further research should test whether the SCe data make it possible to expand the model in order to shed additional light on the segment of the neural network that represents the image of science described by the PIKA model (interactions among four dispositions, e.g. perception, interest, knowledge and action), and to include other important dispositions such as engagement or trust.

In summary, application of the PIKA model and the results of the SCe survey on scientific culture, perception and attitudes towards science and innovation have shed light on how subjective factors such as perception, interest, knowledge and willingness to act affect the image of science in the business sector in Spain. By extension, the present findings enable us to begin to understand the scientific culture of the business sector in this country. We believe that by improving knowledge about the image of science, scientific culture, perception and attitudes towards science, R&D and innovation in the business sector, we will be in a better position to strengthen the engagement of this sector in science funding, R&D and innovation, and possibly to enhance the culture of science and innovation in the business sector.

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No potential conflict of interest was reported by the authors.

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Tables

Table 1. Distribution of the final sample by company size and activity sector.

Sector	Size (Number of employees)					
	Micro < 10	Small 10-49	Medium 50-249	Large ≥250	Total number of companies	Margin of error
Agriculture	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%	

Appendix

Variables included in the study: Script for the SCe questionnaire items (original question and item numbering shown) and descriptive statistics. (Variables included in the structural equation model are shaded.)

Perception

Variables	**Mean(Std. dev.) N**	**Scale and Frequencies (%)**						

Difficulty of doing R&D

Q5.4 *Do you think that for companies, doing research and development or R&D in Spain is very easy, fairly easy, fairly difficult or very difficult?*

		1=Very easy	2=Fairly easy	3=Neither easy nor difficult	4=Fairly difficult	5=Very difficult	DK	NA
	4.0(.9) 604	.3	9.3	4.4	47.8	23.6	14.1	.5

Vision of science

Q6. *When you think of 'science' to what extent do these ideas come to mind?*

		1=Not at all	2=A little	3=To an average extent	4=Quite a lot	5=A lot	DK	NA
1.Progress	4.4(.9) 701	1.4	4.4	11.9	20.9	60.7	.8	.0
2.Risk	3.3(1.3) 694	12.7	14.5	29.2	19.0	22.9	1.8	.0
3.Rigor	3.9(1.1) 697	2.5	8.1	19.5	32.4	36.1	1.4	.0
4.Security	3.8(1.1) 696	3.9	8.3	23.7	29.6	32.9	1.6	.0
5.Usefulness	4.4(.9) 701	2.3	2.8	9.0	24.5	60.4	.9	.0
6.Boredom	1.8(1.1) 696	56.3	17.8	17.0	4.2	3.0	1.5	.1
7.Economic development	4.2(1.0) 701	3.2	4.2	12.9	32.2	46.7	.9	.0
8.Effectiveness	4.0(1.0) 700	2.2	3.5	19.4	37.3	36.7	.9	.0
9.Complexity	4.0(1.1) 700	3.9	7.1	19.8	24.5	43.8	1.0	.0
10.Mistrust	2.3(1.2) 700	32.8	23.3	27.5	8.4	6.9	1.1	.0
11.Interest	4.2(1.0) 701	2.1	4.0	15.8	29.0	48.2	.9	.0

Vision of science (Sum Q6.1 to Q6.11)

	40.2(5.5) 681	Range: 11-54

Balancing public effort in R&D

Q9. *If you were the person in charge of the budget in our country and you had to allocate funds across different budget categories, which category in each pair I'm about to name would you select?*

Science vs.	% select *Science*		% select *Science*
Education	13.5	*Health*	10.6
Defense	93.5	*Care for dependent people*	41.2
Public works	62.2	*Communication and outreach*	96.5
Development aid	35.0		

Role within business of S&T, R&D, scientific knowledge and scientists

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 agree	3=Somewhat agree	4=Strongly agree	5=Fully agree	DK	NA
1.Scientists should play a more important role in business								
	4.2(0.9) 706	1.3	2.9	16.9	30.1	48.6	.2	.02
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								
	3.8(1.1) 700	5.5	6.5	26.3	29.7	31.1	.9	.03
3.When a company collaborates with a research group, it can share, in absolute trust, detailed information on its internal organization decisions								

	Mean(SD) N							
	3.6(1.1) 696	7.0	7.6	29.6	30.0	24.3	1.5	0.0
4.Often we place too many expectations on what science and technology can do for our company								
	3.3(1.2) 702	8.5	14.2	35.1	23.8	17.6	.7	.0
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 toward the company's own interests								
	3.8(1.1) 705	4.0	7.6	27.0	28.4	32.7	.3	.03
6.When making decisions in the company, its values and traditions must be taken into account beyond strictly scientific knowledge								
	3.4(1.1) 700	6.9	11.4	36.3	25.8	18.5	1.0	.0
7.Science and technology can solve any type of business or production problem								
	2.9(1.1) 704	12.1	20.8	39.3	20.9	6.5	.4	.0
8.In companies there is sensitive information that should not be entrusted to scientists who collaborate with them								
	2.9(1.2) 686	12.4	22.4	34.6	16.2	11.3	2.2	.8
9.Scientific knowledge is the best basis for making business decisions								
	3.2(1.0) 703	7.2	15.8	41.5	23.8	11.2	.1	.5

Benefits and risks for companies of investing in R&D

Q15. *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?:*

		1=Don't agree	2=Slightly agree	3=Somewhat agree	4=Strongly agree	5=Fully agree	DK	NA
A company that invests in research and development or R&D...								
1.Makes a very risky investment with a high degree of uncertainty								
	3.2(1.2) 701	8.0	18.0	34.4	22.6	16.1	.7	.1
2.Generates long-term economic benefits								
	4.1(.9) 697	1.2	3.3	16.5	39.7	37.9	1.4	.1
3.Will be forced to lay off workers as its production and service delivery processes become more efficient								
	2.2(1.2) 701	36.2	26.3	21.9	9.5	5.2	.6	.2
4.Will enjoy a competitive advantage								
	4.3(.8) 703	.9	1.7	12.6	35.6	48.6	.5	.1
5.Improves its image in the market								
	4.3(.9) 706	1.1	2.5	11.5	35.7	49.0	.1	.1
6.Wastes time, since it is always more profitable to use knowledge generated by others								
	1.5(.8) 703	62.7	24.0	8.1	4.3	.3	.5	.1
7.Helps to generate new jobs within the company itself								
	3.8(1.0) 702	2.9	4.7	30.4	33.4	27.8	.7	.1
8.May generate risks for health and the environment								
	1.9(1.1) 700	48.0	22.5	20.3	6.5	1.8	.9	.1
Benefits of investing in R&D (Sum Q15.2. Q15.4. Q15.5. Q15.7)								
	16.5(2.6) 688	Range. 6-20						

Institutional confidence

Q16. *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 confidence	3=Some confidence	4=Considerable confidence	5= Great confidence	DK	NA
Professional bodies	3.6(1.0) 691	3.2	10.4	28.2	39.2	16.7	2.1	0.1
Universities	4.0(1.0) 699	2.0	5.0	20.7	38.4	32.8	1.0	0.1
Public research bodies	3.5(1.1) 689	4.6	10.3	28.5	35.2	18.8	1.9	0.7
Governments and public administrations	2.4(1.1) 701	25.4	25.3	33.4	12.0	3.1	0.6	0.2
The media	2.4(1.0) 703	22.1	32.8	31.7	9.9	2.8	0.5	0.1
Consumer associations, ecologists,	2.8(1.1) 693	16.3	20.5	36.4	20.7	4.3	1.9	0.1

NGOs Spanish Council for Scientific Research	4.0(1.0) 678	1.7	3.8	24.8	33.0	32.7	3.6	0.6

Relationship with scientists

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.*

I would be interested if he/she could develop his/her professional work within my company 8.5

I would be interested in formally collaborating with him/her through an agreement between his/her institution and my company 28.2

I would be interested in occasionally knowing his/her opinion about some specific issues related to my sector 42.7

I would be interested in talking with him/her as a matter of personal curiosity. but not on professional issues 11.7

I would not be particularly interested in interacting with him/her for professional or for personal reasons 9.0

Interest

Variables	**Mean(Std. dev.) N**	**Scale and Frequencies (%)**						
Interest Q12. *To what extent do you feel interested in advances in science and technology applied to your sector?*								
		1=Not interested at all	2=Slightly interested	3=Somewhat interested	4=Very interested	5=Extremely interested	DK	NA
	3.9(1.1) 703	5.7	5.5	17.6	32.4	38.3	.1	.5
Obtain information on S&T Q13. *Do you regularly seek information to keep up to date about science and technology in your company?*								
		Yes 71.2	No 28.8					

Knowledge

Variables	**Mean(Std. dev.) N**	**Scale and Frequencies (%)**				
Knowledge of scientific institutions Q8. *Please name institutions you recall which are engaged in scientific and technological research in our country (Name up to 3 different institutions)*)						
		Number of institutions mentioned				
		0 institutions	1 institution	2 institutions	3 institutions	
	.7(.9) 707	60.0	20.2	12.4	7.4	
Knowledge of public and private R&D effort Q10. *Where do you think most investment in research and development, or R&D, comes from in Spain? From the public or private sector?*						
		Public sector	Private sector	Both equally	DK	NA
		21.1	72.2	1.2	5.5	.0
Formal education Q27. *What is the highest level of formal education you have completed?*						
		Primary	Secondary	Secondary pre-university or professional/technical education and training	University undergraduate diploma, technical certificate or bachelor's degree	University postgraduate master's degree or doctorate
		2.6	8.0	32.6	41.1	15.7

Actions

Variables	Mean(Std. dev.) N	Scale and Frequencies (%)			
R&D and innovation activities					
Q17. *In the last 5 years (2011-2015), has your company carried out any of the following activities?*					
R&D activities (Sum Q17.1. Q17.2. Q.17.3)					
	1.5(2.0) 707	Range: 0-6)			
		2=We have done this	1=We tried it but did not complete it	0=We've never tried it	DK
1.Intramural research or R&D (i.e. within the company)		29.1	5.8	64.5	.7
2.Acquisition of extramural research or R&D (i.e. carried out by other public or private organizations)		18.9	3.2	77.2	.7
3. Collaborative research or R&D (i.e., carried out jointly with other public or private organizations)		20.6	3.8	74.9	.7
4. Innovation (in products, processes, organizational methods, etc.)		55.1	2.7	41.9	.3
5. Purchase or license for use of patents, utility models, industrial designs, etc.		10.8	1.7	86.7	.8

Variables	Mean(Std. dev.) N	1=Never	2=Rarely	3 Sometimes	4=Quite often	5=Always	DK	NA
Knowledge building and use in business								
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 behaviors you engage in.*								
1.I imagine different scenarios or try different options, and check what happens in each of them	3.6(1.2) 696	8.6	6.9	27.5	25.9	29.6	1.0	.6
2.I seek updated information based on scientific knowledge	3.4(1.3) 698	13.3	11.9	21.7	30.0	21.8	.8	.6
3.I consult an expert on the subject inside or outside the company	3.5(1.3) 698	10.6	8.8	23.2	30.9	25.2	.2	1.0
4.I follow my own hunches although sometimes I do not know how to explain their logic very well	2.6(1.3) 698	24.7	23.6	24.2	15.6	10.5	.8	.6
5.I try to think how my predecessors in the position would have resolved the matter, so that my decision is in line with company tradition	2.3(1.2) 690	35.9	21.4	22.4	11.8	6.1	.7	1.8
Knowledge building and use in business (Sum Q24.1 to Q24.5)								
	15.4(3.7) 676	Range: 5-25						

Figures

Figure 1

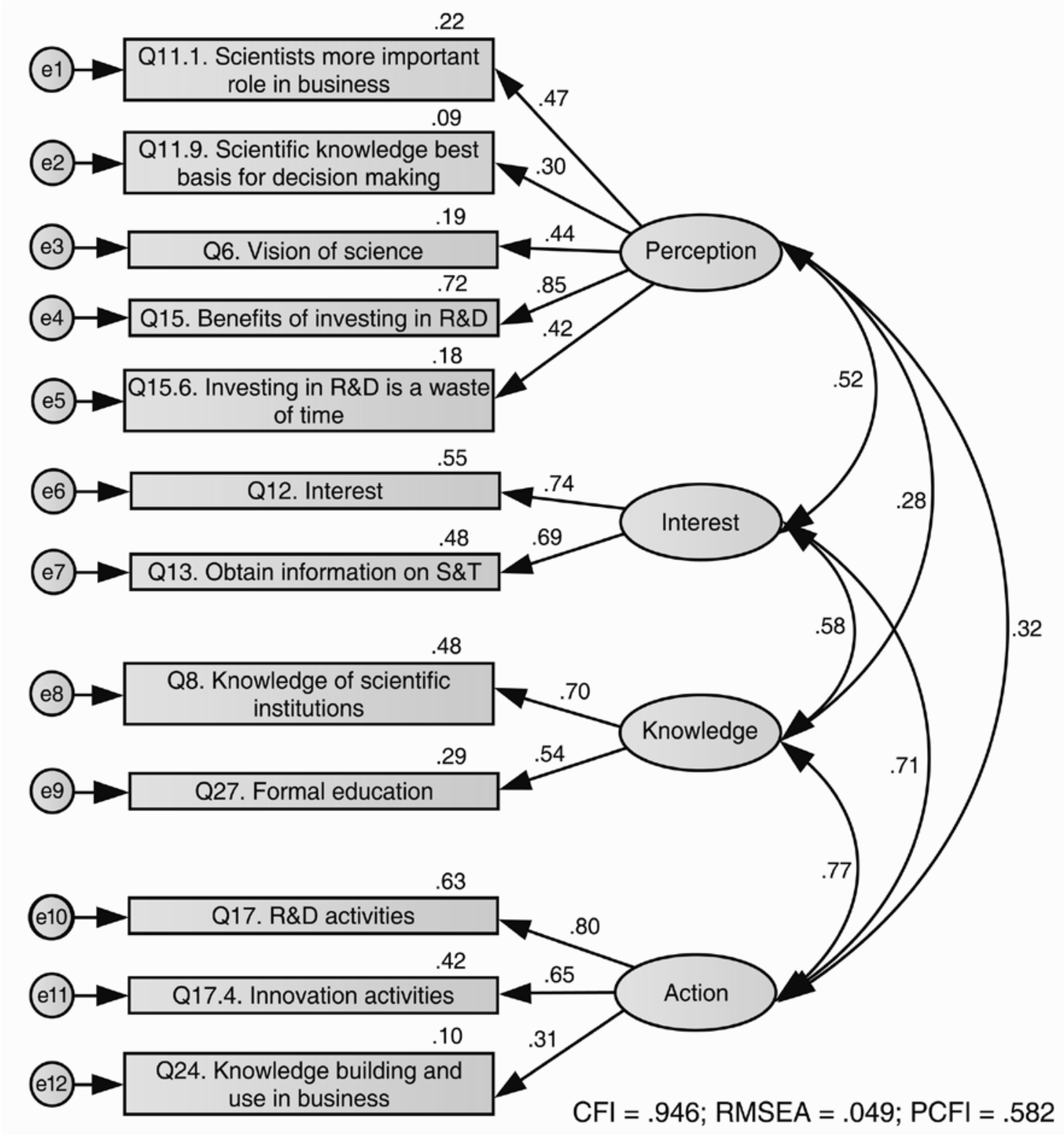

Figure 2

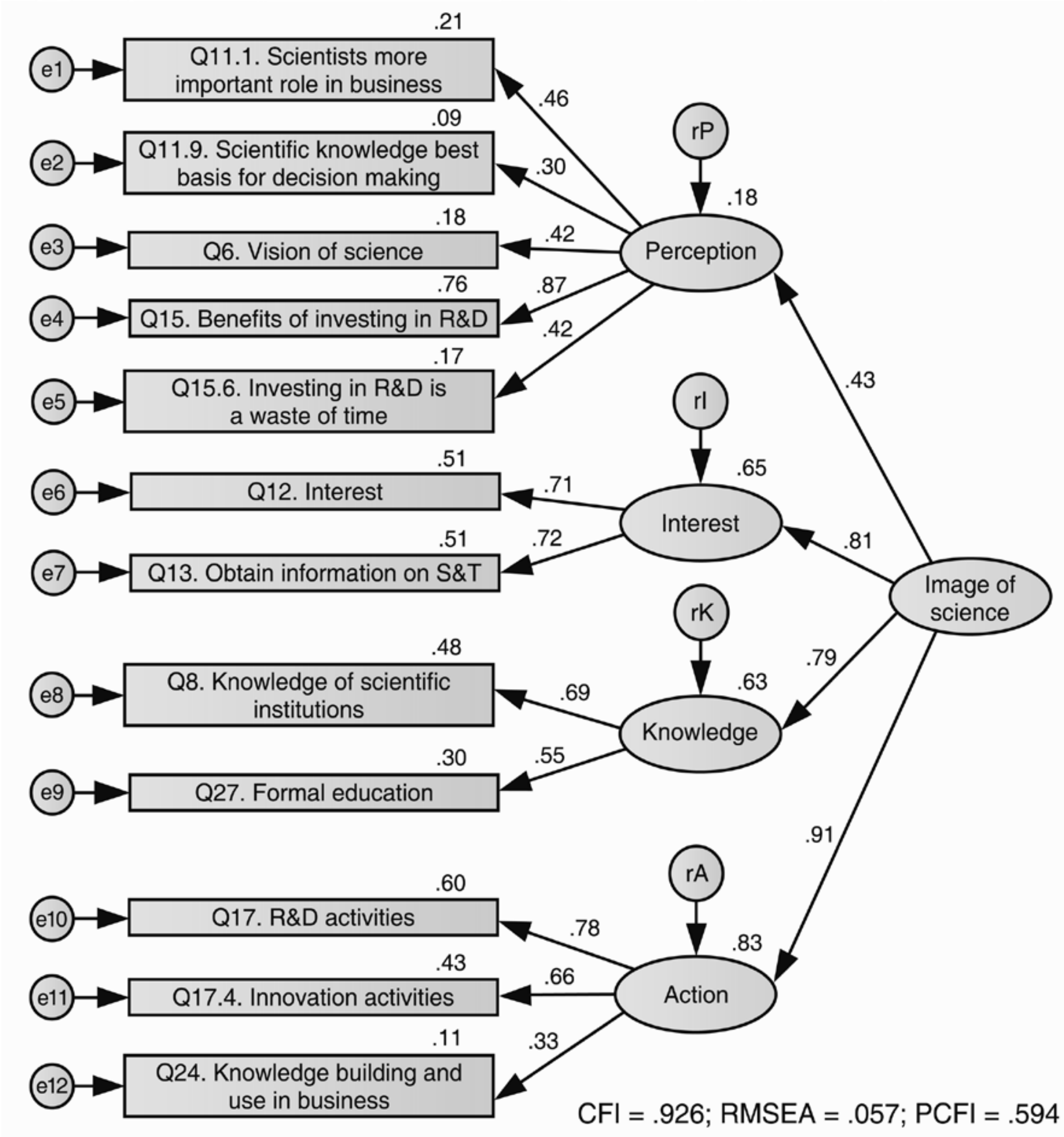
.21
e1
Q11.1. Scientists more important role in business
.46
.09
e2
Q11.9. Scientific knowledge best basis for decision making
.30
rP
.18
e3
Q6. Vision of science
.42
Perception
.76
e4
Q15. Benefits of investing in R&D
.87
.42
.17
e5
Q15.6. Investing in R&D is a waste of time
.43
rI
.65
.51
e6
Q12. Interest
.71
Interest
.51
e7
Q13. Obtain information on S&T
.72
.81
Image of science
rK
.48
.79
.63
e8
Q8. Knowledge of scientific institutions
.69
Knowledge
.30
e9
Q27. Formal education
.55
.91
rA
.60
e10
Q17. R&D activities
.78
.83
.43
e11
Q17.4. Innovation activities
.66
Action
.11
e12
Q24. Knowledge building and use in business
.33
CFI = .926; RMSEA = .057; PCFI = .594

Figure captions

Figure 1. Structural equation model of the PIKA measurement model used for the SCe 2016 survey.

Figure 2. Structural equation model of the PIKA structural model used for the SCe 2016 survey.

Legend to Figures 1 and 2

The measurement model (Figure 1) shows relationships between the theoretical constructs represented by the latent (unmeasured) factors (also called dispositions or constructs) Perception, Interest, Knowledge and Action (ovals) as well as causal relationships of these latent factors with observed (measured) variables or indicators (rectangles).

These relationships are represented as regression or path coefficients between the factors. Single-headed straight arrows from the factors to the variables represent paths showing direct effects, and the numbers alongside arrows indicate factor loadings or linear regression coefficients. Double-headed curved arrows indicate covariances or correlations, with no implied causal interpretation, and the numbers alongside them indicate the regression weight of construct X in construct Y. Numbers above the constructs indicate the percentage of explained variance. Latent factors or constructs are assumed to cause the variation and covariation between the observed variables, but we do not assume that the latent factors completely explain the observed variables.

All variables or indicators described in the Methodology section were included in the initial SEM, but only variables with loadings of .30 or greater were kept in the final SEM. This model required at least two indicators for each factor; hence factors that were explained by only two variables were kept in the model even though the loadings were equal to or less than .30.

Each observed variable was associated with a residual error term (circles) which was also unmeasured. The SEM assumes the existence of a measurement error. In both models, e1 to e13 are the measurement errors of each indicator, i.e. the percentage of variance that the indicator did not explain. For simplicity, residuals and error terms are not depicted; while they are necessary for the analysis, they are not needed to interpret the results. In the structural model (Figure 2), rP, rI, rK and rA are the measurement errors of constructs. For example, rP is the measurement error that arises from the assumption that the Image construct defined Perception (i.e. the percentage of variance not defined by our Image construct).

SEM goodness of fit was determined as RMSEA (root mean square error of approximation) and CFI (comparative fit index). RMSEA values below .05 indicate good fit, while those between this value and .08 are considered reasonable. CFI with values larger than .95 represent reasonable fit. A recommended rule of thumb is a parsimony comparative fit index (PCFI) above .50 with a CFI index around .9.