Journal of Business Research 66 (2013) 2017–2023

Contents lists available at SciVerse ScienceDirect

Journal of Business Research

Open innovation: Factors explaining universities as service firm innovation sources ☆

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ARTICLE INFO

Article history:
Received 1 July 2012
Received in revised form 1 November 2012
Accepted 1 January 2013
Available online 13 March 2013

Keywords:
Service innovation
Open innovation
University–service firm links
Random intercept ordered probit

ABSTRACT

The service innovation literature lacks empirical studies that focus on the links between service firms and universities. This paper aims to contribute to a better understanding of these links. This paper applies the Portuguese version of the Community Innovation Survey (CIS 2006) to obtain data on 967 service firms. The model uses a random intercept in an ordered probit regression to empirically assess which factors influence the collaboration of service firms with universities for innovation related activities. The regression also considers the unobserved firm heterogeneity. The results demonstrate that innovation success, radical innovations, and innovation intensity are crucial to the development of links between innovative service firms and universities.

1. Introduction

The current economic environment is driving firms to become more competitive and innovative. Researchers such as Chesbrough (2003) and Prahalad and Krishnan (2008) show that firms are accessing global networks in which they are able not only to capitalize on all existing knowledge but also to develop their own innovation activities. Such networks represent new means of adapting to competitive contexts, avoiding high fixed costs, offsetting risks, and expanding the scope of innovative success.

Thus, the ability to access these networks becomes a new competitive advantage that is capable of providing long-term strategic competitiveness. Chesbrough (2003) characterizes this new paradigm of open innovation as a way for firms to collaborate with external innovation sources and to develop new products or services. Competitors, suppliers, customers or universities are some examples of external innovation sources that firms can use in the course of their development of innovation activities.

Furthermore, although countries in the Organization for Economic Co-operation and Development (OECD) face low economic growth and huge challenges for economic development, national governments also seek to stimulate firms' competitiveness by developing strong cooperative links between firms and universities. As a foundation of the National System of Innovation (NSI), universities are renown for their abilities to produce both highly qualified professionals and cutting-edge scientific research, especially related to basic knowledge. More cooperation between firms and universities might quickly bring a greater diffusion of knowledge, better results from firm innovation, and training programs for students. Therefore, a need exists to understand just which types of firms now collaborate with universities on innovation activities.

Although this paper aims to explore the types of firms that adopt universities as innovation sources, the focus is only on innovative service firms because the service sector makes an overwhelming contribution to sustaining employment and wealth creation in OECD countries. However, in the literature on innovation, the industrial sector receives the greatest attention. Indeed, few studies focus exclusively on innovation in services (e.g., Adame-Sánchez & Miquel-Romero, 2012; Flikkema, Jansen, & Van der Sluis, 2007). Hence, the paper's objective is to contribute to a better understanding of this field. This paper also represents an innovative contribution to the study of the linkages between firms and universities. Other studies exist that focus on service and industrial sectors, such as Negassi (2004), Schmidt (2005), and Segarra-Blasco and Arauzo-Carod (2008). Some studies focus only on the industrial sector, such as Cohen, Nelson, and Walsh (2002) and Laursen and Salter (2004).

This paper provides empirical evidence on the determinants of innovation activities between firms and universities in a sample of 967 Portuguese service firms. The data set comes from the Community Innovation Survey (CIS 2006) and covers the period between 2004 and 2006. The Portuguese case is especially interesting as the country carries out less investment in research and development (R&D) than any other European country.

☆ The authors thank Manuel Mira Godinho and Manuel Laranja for the comments made on earlier versions of this paper. We are also grateful to GPEARI-MCTES for providing the data. Isabel Proença and Vitor C. Gonçalves acknowledge the financial support from the FCT (Fundação para a Ciência e Tecnologia) through the PEst-OE/EGE/UI0491/2011 program.

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http://dx.doi.org/10.1016/j.jbusres.2013.02.027

Yet Portugal has faced the problem of economic competitiveness since the turn of the century, which is similar to other southern European countries. Despite this, Portugal is slightly distinct from others as the service sector holds far greater relevance to the economy. Eurostat (2011) concludes that in 2008, the Portuguese service sector was responsible for 60% of the business sector's R&D expenditures; while in countries such as Germany, Italy, and Spain, the service sector was responsible for only 11%, 26%, and 47% of the national business sector's R&D respectively. Taking only the service sector weighting into consideration for EU-27 economies, the Portuguese service sector has the fourth highest contribution to the business sector's R&D expenditures behind only Bulgaria, Estonia, and Cyprus at 65%, 64%, and 62% respectively. Thus, this research constitutes an opportunity to better understand the role of service sectors within the framework of NSIs.

The remainder of the paper is organized as follows. Section 2 outlines the theoretical and empirical background of the role of universities in the innovation process, before presenting the hypotheses. Section 3 introduces the data and method, and Section 4 details the econometric study. Section 5 comprises the discussion of the main results and the conclusion.

2. Theoretical and empirical background

2.1. The role of universities as an innovation source for firms

The research on the role of innovation sources in firms has a long history that consists of a large number of academic papers (Chesbrough, 2003; Gibbons & Johnston, 1974; Mol & Birkinshaw, 2009; Mueller, 1962; Von Hippel, 1988, 2006). Von Hippel (1988) defines functional sources of innovation as the types of economic actors (users, suppliers, producers, or others such as universities) that contribute towards the development of product, process, or service innovations. Additionally, GPEARI (2008) suggests that information sources for innovation are the sources that provide useful information for new innovation projects or those that contribute to the conclusion of innovation projects in progress. Newer innovation models strongly emphasize the role of the interaction between firms and a wide number of innovation sources, especially lead users, suppliers and universities, as well as other public entities (Herrera, Muñoz-Doyague, & Nieto, 2010; Lundvall, 1992; Niosi, 1999; Von Hippel, 1988, 2006). For instance, the open innovation model argues for firms working with external knowledge sources (Chesbrough, 2003). This model defends this path as developing new competitive advantages, especially in terms of companies designing and developing new products, services, or ventures. The open innovation concept illustrates how the most valuable ideas and innovations might derive from either internal company or external environments and may also be susceptible to market launches through either internal or external paths to the company.

Chesbrough (2003) suggests that firms that excessively focus on developing new ideas internally tend to miss a great deal of opportunities that a wide range of actors external to the company might provide. Therefore, a fundamental part of the innovation process now focuses on this need to search out new ideas and to partner with firms developing new products and services, as opposed to investing large amounts of time, money, and other resources in the production of radical new innovations.

According to Chandy and Tellis (1998), the distinction between incremental and radical innovations is due to the substantial difference in the technology (whether current or new) and to the consumer needs (whether existing or new) being met. Radical innovation incurs greater risks because this type of innovation incorporates new technology and meets new consumer needs and demands. This risk explains why, typically, radical innovation also generates higher returns (Skarzynski & Gibson, 2008). However, radical innovations need new knowledge, and sources of new knowledge come from the fundamental research undertaken by universities. Universities are a special case as an innovation source both because of their research potential and the diversity of their research groups (Santoro & Chakrabarti, 2002). Furthermore, the literature emphasizes the role of universities. Even before Lundvall's (1992) NSI model, Nelson (1993), and the Triple Helix model in Etzkowitz and Leydesdorff (2000), research places a major focus on universities.

In Portugal, the role of universities in the innovation system is particularly important as clearly demonstrated by a range of statistics (Eurostat, 2011): in 2008 Portuguese R&D investment stood at only 1.51% of the gross domestic product (GDP) (EU-27: 1.92%), government R&D expenditure accounted for 0.11% of the GDP (EU-27: 0.24%), the private sector accounted for 0.75% of the GDP (EU-27: 1.21%), while the expenditure of the higher education sector accounted for 0.52% (EU: 0.44%). These figures show that in Portugal in 2008, only the university sector invested relatively more in R&D activities than their European counterparts. The numbers also reflect the increasing role of universities in the intensity of R&D that is taking place in Portugal; in 2004, university R&D expenditure accounted for just 0.27% of the GDP.

Universities are also drivers of knowledge diffusion because they can exert strong influences over regional innovation ecosystems by establishing interactions with local firms or economic actors (Brown & Duguid, 2000). This influence reflects the importance endowed to universities and their perceived position as one of the pillars of NSIs (Fagerberg, Mowery, & Nelson, 2005). The creation of new knowledge at universities fosters the development of the radical innovations able to sustain new competitive advantages and the firms' entries into new markets. As Spencer (2001) states, the interaction between firms and universities increases the number of innovations that firms produce. This interaction between firms and universities most commonly involves research, contract research, and consultancy based relations (Perkmann & Walsh, 2007).

However, interactions between firms and universities are also shaped and conditioned by what Gemünden and Ritter (2004) call network competence, which is the firm's ability to establish and benefit from relations with other organizations. The same authors suggest that firms with higher network competence levels are better at attracting and retaining customers, suppliers, research centers, and other partners. Furthermore, these firms are better at maintaining their innovation networks and accessing the various knowledge sources for their innovation projects. However, in spite of the rich depth of the literature on interactions between universities and firms, many studies adopt only small samples commonly associated with the industrial sector (Hicks, Breitzman, Olivastro, & Hamilton, 2001).

2.2. Hypotheses from the literature

This study maintains that the level of success for a firm's innovation policy extends beyond the ability to launch new products or services into the market. This study uses the same approach as Gemünden and Ritter (2004) who define innovation success as the junction of the success related to the product or service innovation coupled with the success of the process innovation. These authors conduct a survey that asks German firms how they classify the level of success in product and process innovations. Although product metrics are easier to define and measure, process analysis is also a good complement for evaluating the success level of the innovation activities.

Thus, this study adopts the approach of Gemünden and Ritter in order to propose a new strategy for studying the relationship between firms and universities. This strategy acknowledges that innovation success means that firms are able to transform their new product and service development into innovation policy, thereby ensuring that the firm can broaden its product or service portfolio, enter new markets, increase sales, reduce unit labor costs, increase service quality, and so on. Firms with higher levels of innovation success

tend to access more external partners as a natural consequence of their network competence (Gemünden & Ritter, 2004). The CIS questionnaire reports the effects on innovation that this research uses to build the innovation-success variable.

H1. The higher the firm's level of innovation success is, the more intensive its recourse to cooperation with universities.

Within their innovation output strategy, firms can choose from two types of innovation: incremental or radical. To produce radical innovations, firms often need to make considerable investments in innovation activities with lower chances of success than those of incremental innovations, but with correspondingly greater rewards (the higher the risk, the higher the expected return). The name given to these firms is innovation leaders. Skarzynski and Gibson (2008) recommend access to external partners for innovation as a means of leveraging the set of strategic skills necessary to produce radical innovations. However, Laursen and Salter (2006) maintain that, when companies decide to invest in radical innovations, they might resort to fewer information sources out of the expectation that they need to work more closely with those chosen.

Furthermore, for developing radical innovations, firms particularly use consumers, suppliers, and universities (Rothwell, Freeman, Jervis, Robertson, & Townsend, 1974; Urban & von Hippel, 1988; Von Hippel, 1988). Therefore, one can predict a greater preference for links with academic centers (Abernathy & Utterback, 1975; Chesbrough, 2003; Congregado, Golpe, & Van Stel, 2012). Zucker, Darby, and Brewer (1998) provide one example of how biotech firms turn to universities when seeking to develop radical innovations.

H2. Firms that are innovation leaders are more likely to use universities intensively in their innovation activities.

Tether and Swann (2003) conclude that firms in the knowledge intensive business service (KIBS) sector proportionately use greater access in public information sources for innovation. These sources include universities, laboratories and public research institutes. Chesbrough (2003) examines several KIBS firms, including Xerox, IBM, and Intel before concluding that all of them resort to external innovation sources. Their need stems from the great rivalry experienced in this sector but also because of the active technological capabilities that these firms use to enable them to leverage their technological base (Grandstrand & Sjolander, 1990). Hence, this need also explains their propensity towards developing further innovations.

H3. Service firms that belong to the KIBS sector are more likely to intensively use universities.

Several OECD member governments have sought to boost the development of their NSIs by nurturing interactions between universities and firms. Several public programs have backed the development of innovation skills within organizations and within the framework of promoting national competitiveness. The data from the CIS 2006 show how many Portuguese firms register trademarks, and because trademarks are a frequently used indicator of innovation output (Mendonça, Pereira, & Godinho, 2004), the study here also expects that service firms registering trademarks interact more intensively with universities.

H4. Firms registering trademarks are more likely to rely extensively on universities.

The previous studies highlight the importance of variables such as age, size, or R&D intensity in understanding the access to universities as an innovation source. Thus, this research introduces the innovation-intensity variable that represents the ratio between the innovation expenditure and the firm's sales. Although the first hypothesis has a relation to output indicators, this hypothesis has a relation to input indicators. Cohen and Levinthal (1989) suggest that the level of a firm's scientific and technological capacity has a relation to incorporating the knowledge derived from public sources. Investment in innovation not only enhances the actual ability to develop new products, services and processes but also absorbs externally generated knowledge (Cohen & Levinthal, 1990; Lapiedra, Palau, & Reig, 2012). Thus, this study assumes that service firms with high levels of innovation intensity are better prepared to explore universities in greater depth as information sources for innovation activities.

H5. The higher the innovation-intensity level, the greater the firm's reliance on universities.

In addition, this study focuses on firm size. Firm size is by far the most commonly adopted variable in the studies on the linkage between universities and firms, even though these studies focus primarily on the industrial sector (Arundel & Geun, 2004; Cohen et al., 2002; Laursen & Salter, 2004; Lee & Huang, 2012; Link & Rees, 1990; Schartinger, Schibany, & Gassler, 2001). Because the research does not widely use this variable for depicting the relations between universities and service firms, this research also considers firm size within this new context.

This study expects larger firms to display a greater propensity to turn to universities because they are in possession of greater resources enabling them to better exploit new knowledge. Larger firms are also more likely to use more qualified staff with better training and a higher propensity for scientific research, which ensures they consolidate their links with universities.

H6. Larger firms tend to access universities more intensively.

3. Empirical model and data

3.1. Empirical model

This section introduces the model that explains the intensity with which firm i accesses universities in its innovation activities. The model achieves this explanation through the characteristics of the firm in terms of structural factors, search strategy, and innovation success, among other factors. The specification of the model relies on the hypotheses stated in the previous section. The aforementioned intensity is y_i^* $(i=1,\ldots,n)$ and can be determined by

$$y_i^* = \mathbf{x}_i\boldsymbol{\beta} + u_i \quad i = 1,\ldots,n \tag{1}$$

where $\mathbf{x}_i$ is a vector of the explanatory variables including the characteristics of the firm mentioned above, $\boldsymbol{\beta}$ is a vector of the unknown coefficients that measure the impact of the variables on the intensity of university usage by firms, and u_i is an error term with a standard normal distribution. Estimating $\boldsymbol{\beta}$ from Eq. (1) is not possible because y_i^* is not directly observed, which makes y_i^* merely a latent variable. Instead, researchers observe the levels of intensity usage that each firm reports (which depend inherently on y_i^*), thereby resulting in the ordered variable y_i. The latter variable is thus the degree to which firm i accesses universities in its innovation activities, and the definition of the variable is

$$\begin{aligned} &y_i = 0 \quad \text{if} \quad y_i^* \le a_{1i} \qquad i = 1,\ldots,n \\ &y_i = 1 \quad \text{if} \quad a_{1i} < y_i^* \le a_{2i} \\ &\vdots \\ &y_i = J \quad \text{if} \quad y_i^* > a_{ji} \end{aligned} \tag{2}$$

where $a_{ji} = \alpha_j + \varepsilon_i$ $(j=1,\ldots,J;\ i=1,\ldots,n)$, with ε_i a random variable independent of u_i and normally distributed with mean zero and variance σ^2. Tutz and Hennevogl (1996) introduce a similar specification for ordered

data to deal with unobserved heterogeneity. The usual models such as the ordered probit consider that the thresholds adopted to define the reported ordered variable are the same for all respondents and equal to α_j respectively. These thresholds imply that the respondents all have the same perceptions about the limits of the intensity that define the particular usage level. But in Eq. (2), the thresholds are random and therefore particular to each respondent, thus explicitly introducing unobserved firm heterogeneity into the model. This approach is better in keeping with reality given that some subjectivity is most probably present in the evaluations by the respondents on their own firm's access to universities.

From Eqs. (1) and (2) and using the fact that u_i is normally distributed, the following probabilities exist:

$$\begin{aligned} &P(y_i = 0|\mathbf{x}_i, \varepsilon_i) = P(y_i^* \le \alpha_1 + \varepsilon_i) = \Phi(\alpha_1 + \varepsilon_i - \mathbf{x}_i\boldsymbol{\beta}) \qquad i = 1, \ldots, n \\ &P(y_i = 1|\mathbf{x}_i, \varepsilon_i) = P(\alpha_1 + \varepsilon_i < y_i^* \le \alpha_2 + \varepsilon_i) = \Phi(\alpha_2 + \varepsilon_i - \mathbf{x}_i\boldsymbol{\beta}) - \Phi(\alpha_1 + \varepsilon_i - \mathbf{x}_i\boldsymbol{\beta}) \\ &\quad\vdots \\ &P(y_i = J|\mathbf{x}_i, \varepsilon_i) = P\left(y_i^* > \alpha_J + \varepsilon_i\right) = 1 - \Phi\left(\alpha_J + \varepsilon_i - \mathbf{x}_i\boldsymbol{\beta}\right). \end{aligned} \tag{3}$$

The unknown coefficients, $\boldsymbol{\beta}$, $\alpha_j (j = 1, \ldots, J)$, and σ^2 are estimated from the probabilities in Eq. (3) by the maximum likelihood. This specification is equivalent to considering an ordered probit with a random intercept (for a detailed survey on models for ordered response variables, see Boes & Winkelmann, 2006).

3.2. The data

The data comes from the 5th Community Innovation Survey conducted in Portugal (CIS, 2006). The Oslo Manual describes the method and types of questions applied in this survey, which is managed by Eurostat across the European Union (OECD, 2005). Each CIS is extensively tested before implementation. Since its first application in the 1990s, the survey has been subject to continuous review.

The survey questions the firms directly to ascertain what information sources they use for their innovation activities. The CIS lists ten different kinds of information sources for innovation that includes suppliers, customers, and universities. The questionnaire has fifteen pages that comprise all of the necessary settings in order to minimize the response subjectivity.

The National Institute of Statistics (INE) establishes the sample of respondents in Portugal. The data were gathered between June 26 and November 16, 2007, for the survey of firm innovation activities during the 2004 to 2006 calendar years. The sample comprises 7488 firms based on a combination census (for firms with more than 250 employees) and random sampling without subject replacement used for all other firms (with more than five employees). The total number of valid responses is 5031. The information is managed through a purpose-designed online platform and stratified by the two-digit NACE code, by size (the number of employees) and by regional distribution (NUTS II). The sample comprises 967 Portuguese service sector firms.

4. Econometric analysis

4.1. Dependent variable

The definition of the dependent variable is the degree to which firms use universities as an information source to provide information for new innovation projects or to contribute to the completion of existing innovation projects. This variable is a categorical variable with four degrees. The variable assumes the value of zero when the firm states no use of universities as an information source, one if the firm responds low use, two if the firm responds moderate use, and three when answering high use. Because this variable stems from issues relating to the respondent's value judgments, the variable should not be taken as an accurate measure of the extent of the access to universities as innovation sources. This problem is typical for this kind of questionnaire because a degree of subjectivity always exists in the respondents' answers. This latent subjectivity is introduced into the modeling by means of a random intercept ordered probit.

4.2. Independent variables

The model introduces the variable innovation success, which represents a firm's success in obtaining positive outcomes from its innovation activities such as entry into new markets, an increasing market share, and reduced unit labor costs. Innovation success assumes a high value when success is greater and a low value when success is lower. The variable is built by aggregating the survey's listed effects of innovation related to products and processes, and returns a high degree of Cronbach's alpha reliability at 0.83.

Regarding the innovation profile, this research suggests identifying highly innovative firms using radical innovations. Innovation leader is an explanatory variable that captures all of the firms that have launched radical innovations into the marketplace (through the question “some of the goods or services innovations launched into the market by your firm during the 2004 to 2006 period were new to the firm's market” on the questionnaire). The assumption is that these firms are innovation leaders in accordance with the criteria of Chandy and Tellis (1998). An alternative variable that the study adopts as a possible measure for the firm's innovation profile is the radical innovation performance. This variable represents the percentage of radical innovation sales out of the firm's total revenues (through the question “New or significantly improved goods and services introduced during 2004 to 2006 that were new to your market, as a percentage of total turnover” on the questionnaire). Higher values indicate greater success for the market launch of radical innovations, and thus the innovation profile of a more aggressive firm. This variable is continuous and based on the Laursen and Salter (2006) study. Traditionally, studies in this area rely greatly on structural factors, such as firm size or innovation intensity.

The KIBS is a variable that assumes the value of zero when the firm does not produce knowledge intensive business services or a value of one when the firm does. The KIBS variable is in regard to ICT and R&D service activities (which are achievable by SIC code). Finding industry dummies in studies focusing on the firm–university link is not common, because most studies focus on specific industries. However, when working on broader samples, the research expects behavior relating to access to innovation sources to differ across industries (Landroguez, Castro, & Cepeda-Carrión, 2011; Tether & Swann, 2003).

The trademark variable represents service firms reporting they have registered trademarks between 2004 and 2006. The model also assumes an alternative innovation output measure that is broader than trademark: intellectual property rights (IPR), which takes a value of one when a firm registers copyrights, patents, trademarks, or industrial layouts. Data is collected through the question “during the 2004 to 2006 period your firm recourse to the below means to protect their innovations” on the questionnaire.

The variable that measures the innovation intensity considers the investment in activities, equipment, and staff in R&D. Therefore, the variable innovation intensity is the ratio between the total innovation expenditure and the turnover (both quantities for the calendar year of 2006) and is also obtained from the information provided by CIS (through the question “indicate the expenditure amount regarding each innovation activity for only 2006” on the questionnaire). For this ratio, observations with innovation intensity values higher than one are eliminated as the study assumes they represent statistical errors. Further, the study considers firm size in the model in keeping with the studies by Cohen et al. (2002), Laursen and Salter (2004), and Mohnem and Hoareau (2003). To analyze the effect of firm size, the study introduces three dummy variables: Small for firms with less than 50 employees, Medium for firms with between 50 and 249

employees, and Large for firms with more than 249 employees. Another possible representation of firm size is the logarithm for the level of revenue (expressed in thousands of Euros).

Table 1 presents the descriptive statistics for the data. The average degree to which service firms use universities as an innovation source is less than one, and thus no use and low use are the most frequent answers in the survey. Small firms (51.7%) compose the majority of the sample with large firms representing only 18.3% and KIBS firms representing approximately 11%. Service firms also have an innovation success level with an observed average approximate to the median use (category 2). Regarding the commercial performance of radical innovations, that is, the sales of new products or services significantly improved in their industry; firms respond that this performance represents 8% of their sales, on average, for the period between 2004 and 2006. However, the standard deviation is more than double the average, which indicates a high dispersion compared to average values. One can expect certain industries are more inclined to develop and commercialize radical innovations than others. Regarding innovation leader, on average, about 35% of the firms state that they have launched radical innovations into the market. The average intensity of the innovation is 3.3%, a low value, but with a standard deviation almost three times greater, also indicating the existence of large variations in this item within the sample. A final note as regards trademark and IPR: 20.9% and 23.6% of the sample report the use of these intellectual property measures respectively.

After considering the results in Table 2, and particularly column 1, the conclusion is that access to universities positively correlates with all of the variables except for the variable Small. The strongest correlation is the level of innovation success followed by KIBS and innovation leader.

4.3. Estimation results

To make inferences about the aforementioned hypotheses, the study estimates the random intercept ordered probit regression introduced in Subsection 3.1, because the dependent variable is discrete and inherently ordinal (taking values between zero and three) and the unobserved firm heterogeneity needs to be accounted for. The *gllamm* program written for STATA to estimate Generalized Linear Latent and Mixed Models provides the estimates of the unknown coefficients (for details about this procedure, see Rabe-Hesketh, Skrondal, & Pickles, 2005). Table 3 provides the results. Four different models are estimated that differ according to the variables used to measure the firm dimension and behavior concerning radical innovations. For instance, to analyze the impact of firm size, either Small, Medium, or Big are used as dummy variables based on the number of employees or the logarithm of the level of revenues. This table also contains the results from applying a specification test to each model.

The results show that for model 1 all of the coefficient estimates are positive and statistically significant at the 5% level except for trademark. Model 2 tests all of the previous model variables except for innovation leader, which radical innovation performance replaces. This new variable does not prove statistically significant with the same also true for model 4. Models 3 and 4 test the dimension effect through the dummy variables Small and Big instead of the logarithm for the level of revenues, and results show that Big is not statistically significant. Therefore, the logarithm for the level of revenues is preferable to test the firm size effect and the variable innovation leader instead of the radical innovation performance is preferable to analyze the effect of the radical innovation output. All the same, in accordance with the results, the conclusion is that the dimension is statistically relevant, with smaller firms tending to display a lower intensity of accessing universities in their innovation processes, which, in turn, gives support to H6.

The overall conclusion is that all of the models lead to similar and coherent conclusions. In all of the cases, the variance in the random effect of the thresholds is statistically significant at the 1% level, which provides strong empirical support that firms have heterogeneous behavior in defining the degree to which they use universities and consequently the adequacy of the random intercept term as a means of capturing unknown firm heterogeneity. Further, the four regressions report very close and robust fit indicators (although the log-likelihood is not comparable for estimations with differing numbers of observations where the difference is due to the missing values in some variables) and no evidence exists of a misspecification at the 5% level in any case. However, results from model 1 are more interesting due to the statistical significance of the included variables.

The sign of the estimated regression coefficients in an ordered dependent variable model gives the direction of the effect of the explanatory variables in the latent y_i^*, here the intensity of university usage by service firms. Consequently, these estimates can test the adequacy of the hypotheses stated in Section 2. However, because the latent variable cannot be observed, measuring the marginal effects from the explanatories on the firms' propensity to use universities to a certain degree is more elucidative. Because these propensities are nonlinear, the marginal effects depend on the characteristics given in the explanatory variables and consequently are not constant but specific to the firm. Therefore, for all of the firms in the sample, model 1 calculates the average of the marginal effects of the regressors on the probability of each level of university usage. Table 4 presents the results.

The results in Table 4 demonstrate that the absolute value of the average marginal effects on the probability of not accessing universities is greater than the average marginal effects for all other probabilities. An increase in the variables induces, on average, a greater probability of firms turning to universities as sources of innovation and decreases the probability of firms not turning to universities. As an example, the figures in Table 4 show that if the revenue level increases 10%, then the probability of a firm not using universities decreases 0.17 percentage points (p.p.) and the probability of high use increases by 0.05 p.p. But, if the firm produces KIBSs, then the probability of not using universities decreases by 18.00 p.p. and increases the probability of having high use by 6.40 p.p.

In conclusion, strong empirical support exists for H1. The variable innovation success is positive and statistically significant, and hence those service firms that are more successful in their innovation activities are also those displaying a greater propensity for accessing universities as innovation resources. The marginal effects of this variable demonstrate that its impact is particularly significant at the levels of moderate and high usage. These results prove Gemünden and Ritter's (2004) assertion that the most successful innovation firms tend to turn to external partners. Also, according to Cohen and Levinthal (1990), firms that gain more success from their own innovation activities also tend to display high absorption capacities and expect their technological bases to represent sustainable competitive advantages.

Empirical validation exists for the second hypothesis that posits that innovation leaders constitute the firms most likely to intensively

Table 1
Descriptive statistics.

Variable	n	Mean	Std. dev.	Min	Max
Universities	967	0.632	0.954	0	3
Log revenue level	967	8.775	1.929	1.567	13.608
Small	967	0.517	0.500	0	1
Medium	967	0.300	0.458	0	1
Big	967	0.183	0.387	0	1
KIBS	967	0.111	0.314	0	1
Innovation success	930	1.749	0.694	0	3
Innovation leader	967	0.353	0.478	0	1
Radical innov. performance	942	0.081	0.185	0	1
Innovation intensity	966	0.033	0.088	0	0.939
IPR	967	0.236	0.425	0	1
Trademark	967	0.209	0.407	0	1

Table 2
Correlations between variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12
Universities	1.00											
Log revenue level	0.09	1.00										
Small	−0.08	−0.62	1.00									
Medium	0.05	0.23	−0.67	1.00								
Big	0.04	0.53	−0.49	−0.32	1.00							
KIBS	0.18	−0.07	0.02	0.03	−0.06	1.00						
Innovation success	0.29	0.07	−0.02	−0.01	0.04	0.06	1.00					
Innovation leader	0.18	0.15	−0.12	0.07	0.07	0.24	0.16	1.00				
Radical innov. perform.	0.12	−0.05	0.02	0.00	−0.02	0.19	0.14	0.58	1.00			
Innovation intensity	0.14	−0.17	0.10	−0.07	−0.05	0.18	0.14	0.12	0.12	1.00		
IPR	0.10	0.16	−0.11	−0.01	0.15	0.14	0.11	0.19	0.10	0.09	1.00	
Trademark	0.09	0.17	−0.12	−0.01	0.16	0.12	0.10	0.17	0.08	0.09	0.92	1.00

access universities in their innovation activities. The variable innovation leader generates positive and statistically significant effects with the marginal effects returning higher values in cases of moderate and high firm usage. This evidence corroborates the position taken by Skarzynski and Gibson (2008) that firms striving for breakthrough innovations and marketing success should seek extensive access to external sources. All of the other hypotheses also receive strong empirical support in accordance with the statistical significance of the coefficients estimated and the marginal effects of variables such as KIBS, innovation intensity, and log revenue level. The trademark variable proves to be the exception as the estimated coefficient and the marginal effects are not statistically significant. Therefore, the conclusion is that the model empirically justifies all of the hypotheses with the exception of H4. Furthermore, innovation intensity is the variable with the greatest marginal effects for levels 1, 2, and 3 of university usage.

Table 3
Random intercept ordered probit regression portraying the incidence of university knowledge usage in the innovation activities of service firms, 2004–2006.

Variables	Model 1	Model 2	Model 3	Model 4
Big			−0.014	−0.014
			(0.129)	(0.130)
Small			−0.223**	−0.243**
			(0.099)	(0.099)
Log revenue level	0.052**	0.071***		
	(0.024)	(0.024)		
KIBS	0.516***	0.555***	0.506***	0.547***
	(0.144)	(0.140)	(0.145)	(0.144)
Innovation success	0.574***	0.578***	0.588***	0.604***
	(0.071)	(0.072)	(0.078)	(0.082)
Radical innov. perform.		0.359		0.338
		(0.219)		(0.226)
Innovation leader	0.253***		0.259***	
	(0.092)		(0.093)	
Innovation Intensity	1.036**	1.141**	0.998**	1.060**
	(0.479)	(0.464)	(0.484)	(0.474)
Trademark	0.039	0.056	0.057	0.088
	(0.105)	(0.104)	(0.107)	(0.107)
α_1	2.098***	2.212***	1.554***	1.516***
	(0.266)	(0.272)	(0.176)	(0.184)
α_2	2.620***	2.729***	2.082***	2.043***
	(0.273)	(0.281)	(0.187)	(0.197)
α_3	3.487***	3.575***	2.959***	2.909***
	(0.278)	(0.290)	(0.204)	(0.220)
σ^2	0.155***	0.151***	0.178***	0.179***
	(0.035)	(.033)	(0.045)	(0.058)
n	929	904	929	904
Log-likelihood	−883.79	−864.74	−883.38	−865.82
R^2	0.32	0.29	0.35	0.35
Specification test	0.17	−1.73**	0.23	−0.78

The standard errors are between parentheses. The ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. The null hypothesis that the model is correctly specified is not rejected at the 5% level. The coefficients α_j are the thresholds' means and σ^2 is their variance.

5. Discussion and conclusion

This study's results point to new research topics, such as the impacts of a firm's level of innovation success or a firm's adoption of a radical innovation strategy. Looking at the analysis of both innovation success and innovation leaders, successful firms are also those that tend to rely more on universities. Therefore, a causal relationship exists between successful innovation and access to external sources such as universities. The fact that successful firms use universities to a greater extent in their innovation activities might indicate the firms' recognition of the role that universities play in knowledge development. This recognition therefore enables managers to define better and more open innovation strategies and to define a network of external partners that should include universities. However, access to universities varies in intensity from industry to industry (Segarra-Blasco & Arauzo-Carod, 2008). The KIBS firms tend to be very innovative, and therefore the expectation is that this drive for new knowledge brings these firms into contact with universities. Structural factors, such as firm size or innovation intensity, do shape and condition the propensity of firms to access universities. In the current economic environment and in the context of huge business rivalries, governments are in a position to develop a new strategic vision for higher education in order to restructure one of the pillars of the NSI. In doing so, governments can also ensure greater national economic competitiveness through enabling universities to respond to the particular requirements of local and international markets.

The results validate five of the hypotheses of this research project. However, no conclusion can be reached on whether firms registering trademarks access universities more than those that do not. Although the empirical validation of the first and second hypotheses might constitute a new research topic in this field, the findings do not support H4. This conclusion might be linked to the specific nature of the proxy applied to the hypothesis.

Although this study is based on CIS data, the conclusions need to be analyzed with caution due to the nature of the survey questions and the evaluation of the respondents' subjectivity. However, this study tries to take such effects into consideration in the model by

Table 4
The average marginal effects on the probability of access to universities at given levels. The results are obtained from Model 1 in Table 3.

	Universities = 0	Universities = 1	Universities = 2	Universities = 3
Log revenue level	−0.017	0.004	0.008	0.005
KIBS	−0.179	0.033	0.082	0.064
Innovation success	−0.187	0.046	0.086	0.055
Innovation leader	−0.085	0.020	0.039	0.025
Innovation intensity	−0.337	0.083	0.155	0.100
Trademark	−0.013	0.003	0.006	0.004

incorporating a random intercept in the ordered probit. Even so, caution is still required when applying these conclusions to other contexts. Nevertheless, this work does contribute to the application of CIS data to the service sector, which might stimulate further research in other European countries.

Additional investigation might determine whether the same conclusions hold for the Portuguese industry sector, or alternatively ascertain whether innovation success levels contribute to the access to the university system in other European contexts. Future research needs to understand the reasons or incentives encouraging some firms to seek out external partners or innovation sources to a greater extent than others, and just how this access to external knowledge actually shapes and impacts firms' levels of innovation performance. Other issues remain open to additional research. For example, which types of universities attract the greatest demand; what is the actual frequency of university and innovative firm contacts; how do firms establish and develop such links, in addition to how firms set about assimilating and transforming the knowledge provided by universities into new products and services? These subjects may all prove fundamental to stimulating the new public policies needed to foster and develop strategic competitiveness at the national and individual business levels.

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