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Recruitment of PhD Researchers by Firms

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Abstract

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Keywords:

PhDs recruitment, PhD Mobility, Researcher Careers, R&D Management, Human Resources Management.

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1. Introduction

Ongoing technological progress requires firms to broaden their knowledge base with knowledge from outside. The organizational processes whereby they seek and accumulate new knowledge are complex and imply the development of a broad set of routines that do not only acquire knowledge but also incorporate it into the company's knowledge base (Zahra and George, 2002). One of the major channels used is the recruitment of PhDs, as they transfer up-to-date knowledge previously developed and accumulated in the public R&D system (Zellner, 2003), as well as embodied knowledge (skills) useful for developing and commercializing inventions (Agrawal, 2006). Their importance in the transfer of scientific knowledge has been borne out by the emergence of public programmes to promote their recruitment.

Arguments abound in the literature for and against recruiting academic researchers. On the plus side, they constitute a primary source of scientific knowledge with commercial value (Zucker et al., 1998a), transfer key skills for the development of R&D activities (Almeida and Kogut, 1999) and can increase and improve firms' relations with public R&D systems (Cruz-Castro and Sanz-Menéndez, 2005). There is also evidence in favour of a possible relationship between the recruitment of PhDs and a firm's innovation performance, through stimulation of the inputs and outputs of its innovation process. Detractors say that although PhDs acquire specific skills for monitoring technological developments in the scientific world, their high degree of specialization and strong academic orientation may prevent them from understanding the needs and dynamics of the market (Toole and Czarnitzki, 2009). It has also been

noted that the integration of their knowledge into a company's knowledge base is not automatic, while it can have negative effects on innovation because its complex and highly tacit nature hinder its integration and transfer within the company (Kessler et al., 2000).

Literature on the topic mainly focuses on analysing individual factors predicting preferences for research careers in industry over academia, studies showing those interested in a good salary and downstream research more likely to prefer careers in established firms (Roach and Sauermann, 2010) and that the quality of research is not a decisive criterion in seeking a permanent position (Mangematin, 2000). Another finding is that the private sector's attraction for the scientist is related to their perception of the commercial potential of their research, or related research (Fritsch and Krabel, 2012). Zucker et al. (2002a) found that top academic scientists moved more readily from academia to the private sector if they had a high-level intellectual capital relevant to the commercialization of biotechnology. It has therefore been found that scientists with patenting experience and narrower technological experience value working in firms more highly than those without patents (Crespi et al., 2007; Fritsch and Krabel, 2012).

Studies also show that in certain disciplines like biology, PhDs pay a compensating differential to stay in science, accepting lower salaries to continue researching (Stern, 2004) and that their old university plays a determining role, collaborating with industry to reduce the uncertainties of the labour market (Lanciano-Morandat and Nohara, 2006). Other significant contextual determinants include the fact that PhDs in firms are unlikely to remain in the cities where they studied (Stephan, 2006), as some regions attract more PhDs than others, especially those with more R&D expenditure and research infrastructure (Sumell et al., 2009).

Despite identifying several factors determining the supply of PhDs, these studies have paid little attention to analysing the factors affecting the demand for them. Such scarce literature that there is analyses firms' recruitment of PhDs on the basis of national statistics defining the labour market for scientists. Using firms' structural characteristics, different studies conclude that size, industry sector, previous R&D experience, location and collaboration with universities all significantly influence PhD recruitment (Auriol, 2010; Beltramo et al., 2001; Cruz-Castro and Sanz-Menéndez, 2005). Although they give more specific profiles of firms hiring PhDs, it remains unclear why they do so.

In this paper we study firms' reasons for hiring holders of doctorates and present recruitment as a function of the opportunity to acquire the knowledge and skills such recruits possess. It has been shown that PhDs bring firms elements of knowledge based on complex problem-solving strategies (Zellner, 2003), some of which are acquired during doctoral study and may be useful in linking science with innovation (Beltramo et al., 2001; Lam, 2011), reducing the risk of failure (Agrawal, 2006; Zellner, 2003), connecting firms to knowledge networks (Dietz and Bozeman, 2005; Hess and Rothaermel, 2011; Murray, 2004), attracting external funding and conferring scientific legitimacy on firms in the eyes of the stakeholders (Rao et al., 2008).

2. What we know about academic researchers in firms

The importance of highly qualified human resources to firms' innovation activity has been analysed by different authors who recognize that knowledge is the most important competitive commodity that a company possesses and that it resides

in its human capital (Lepak and Senll, 1999; Levinthal and March, 1993; March, 1991). This literature focuses on graduates with miscellaneous qualifications and follows similar arguments on the role of highly skilled employees in the development of the innovation process, studies agreeing that they generate ideas that set the innovation procedure in motion and monitor the external atmosphere to take advantage of the knowledge generated outside the confines of the company (Chen and Huang, 2009; Laursen, 2002; Shipton et al., 2006). In this context, the employment of academic researchers has become an important object of analysis, for PhDs are trained for research, have the highest educational level and are therefore considered the best qualified manpower for the implementation and diffusion of knowledge and innovation (Auriol, 2010).

Despite the importance given to researchers in firms, a major shortcoming of research analysing their mobility is an imbalance between studies concerning individuals and other levels of analysis, such as the firm. Only a few studies analyse the effects of such researchers joining firms, and these have shown that their recruitment has a positive and significant influence not only on inputs of the innovation process, increasing firms' investment in R&D (Herrera et al., 2010), but also on outputs of the process, through patents and the development of products with a high degree of novelty (Deeds et al., 2000; Ettlíe, 1985; Hermann and Peine, 2011; Zucker et al., 1998ab). In these studies, the development of new products is shown as a function of employing scientists, their knowledge backgrounds being presented as strong predictors of a firm's competitive strategy (Hermann and Peine, 2011). Other studies have gone further and found that the employment of scientists is positively related with the number of new high-growth firms (Eckhart and Shane, 2011), the

rewards of product introduction by new ventures (Rao et al., 2008) and an increase in a firm's market value in high-tech sectors (Darby et al., 2004).

Despite the importance given to these human resources in the innovation process, few studies as yet exist analysing the demand for PhDs in companies and such as there are concentrate on the study of experience in certain specific sectors, mainly in high technology (Zucker et al., 1998a; Zucker et al., 2002 ab). It has been concluded that high-tech companies with a high dependency on scientific knowledge and some absorptive capacity are more likely to hire PhDs (Auriol, 2010; Cruz-Castro and Sanz-Menéndez, 2005). Beltramo et al. (2001) through interviews at companies in France, Spain and the United Kingdom, analyse aspects more concerning company strategy, concluding that the organization of R&D and a firm's tendency to reach external R&D agreements has a positive influence on PhD recruitment. To the best of our knowledge, only Herrera et al. (2010) and García-Quevedo et al. (2012) analyse the factors influencing the recruitment of academic researchers empirically. The former analysed the mobility of researchers in the public R&D into firms, without taking into account their level of qualification, finding that large firms in the high and medium technology sectors, with a high level of formalization of R&D activities had a greater tendency to recruit researchers. The latter study is perhaps the only one to analyse the factors determining the recruitment of PhDs, concluding that the intensity of R&D activities, employing PhDs in the past and university-company relations had a positive and significant influence.

Although the studies described above agree that PhDs are mainly recruited by firms with a clear orientation towards innovation, they do not analyse firms' reasons for doing so in depth. During their doctoral studies and their scientific careers, PhDs develop a range of skills that can be useful to companies when pushing back the

frontiers of innovation and in key roles for developing the innovation process. In the literature we have identified at least five roles for PhDs that may determine firms' tendencies to employ them.

2.1 Firms recruit PhDs to exploit their scientific knowledge

The first role concerns access to scientific knowledge. Much of the knowledge arising from scientific breakthroughs is characterized by its excludable nature. Its high complexity and tacit dimension make its transfer difficult and require the active participation of those possessing it (Zucker et al., 1998b). As a result, for companies working in areas close to basic science, hiring PhDs in the processes of generation and absorption of technological knowledge is of major importance, as they can bring to the company not only the most up-to-date knowledge but also the skills needed to produce and exploit it (Lee et al., 2010). These firms would thus gain competitive advantages from their employees' embodied knowledge, which other firms would not be able to imitate. Given the nature of scientific knowledge, in the literature, the mobility of scientists has been analysed with especial attention in science-driven industries, such as biotechnology, where their presence in companies has been a determining factor for growth and dynamics (Zucker et al., 1998a; Zucker et al., 2002ab; Zucker and Darby, 2007). Firms in traditional sectors or those whose innovation activity is based more on routine and standard practices have shown to be less prone to acquire new knowledge through expert staff mobility (Song et al., 2003). As a result, firms in sectors needing to renew their knowledge base and with an active participation in cutting-edge academic science may be attracted to employing PhDs.

H1: Companies working in areas close to basic science are more prone to employ PhDs.

2.2 Companies employ PhDs to reduce the risk of failure

Once knowledge has been obtained, it is widely accepted that companies must overcome limitations in the process of transforming it into marketable products. Academic researchers may have an important role in reducing the risk of failure at stages of production and commercialization of technology for at least two reasons. On one hand, during their doctoral studies, researchers acquire a wide range of skills and are able to solve a wide range of problems (non-specific knowledge). According to Zellner (2003), these skills are more highly valued in the workplace than those arising from specific knowledge and are applicable to a wide range of business problems that go beyond generating and absorbing technological knowledge. On the other hand, during the processes of invention (trial and error), these human resources acquire a unique knowledge of technology enabling them to propose solutions to improve a product or reduce manufacturing costs. Agrawal (2006, p. 64) shows that during the processes of knowledge transfer from universities, it is important for the company to incorporate the researcher, as much is learned during the refining of inventions, knowledge which “is often valuable in developing intuition regarding how the invention might behave under alternative circumstances”. Academic researchers can accompany the development of technology at all stages and thus contribute to lessening the risk of the innovative process failing.

H2: Firms that have experienced failure in their innovation activity are more likely to hire PhDs.

2.3 Firms contract PhDs when they find themselves in financial difficulties

Thirdly, it has been pointed out that academic researchers may have a major role in companies with financial restrictions and legitimacy in scientific activity. To finance their research activities, companies have to persuade venture capitalists to invest in projects of endemic uncertainty, especially in the high technology sector (Rao et al., 2008). Corolleur et al. (2004, p. 633) present evidence to support the idea that visibility of scientific researchers in firms is a stamp of quality that “increases the firm’s scientific credibility and its ability to attract funding”. In the same vein, Rao et al. (2008) argue that firms in emerging industries must show stakeholders that they can deal with the latest scientific knowledge in their field. They also show that new ventures that acquire legitimacy through the hiring of reputed scientists gain more from their new products than those that do not. Furthermore, in order to fund their research, academics create skills to access public funds by identifying, assessing and exploiting the opportunities that scientific knowledge brings (Herrera et al., 2010).

H3: Companies in financial difficulties are more likely to employ PhDs.

2.4 Firms employ PhDs to access knowledge networks

As few organizations can internally generate all the knowledge necessary for ongoing technological advance, they seek external sources of knowledge through strategic alliances for innovation. The literature states that academic researchers develop social capital during their research careers that they then draw on to create knowledge and interact in different social and professional contexts (Dietz and

Bozeman, 2005). This social capital may be used to bring companies closer to scientific knowledge networks allowing them to form alliances with other researchers, universities and technological centres. The recruitment of PhDs in this field may help to overcome difficulties in finding partners for innovation and in assimilating and exploiting external knowledge (Hess and Rothaermel, 2011). Firms can seek cooperation with other agents through their scientists to fill a particular knowledge gap during the innovation process, to gain legitimacy in the scientific community (Almeida et al., 2011), increase their potential for detecting technological opportunities beyond the confines of the company (Tzabbar, 2009) or to acquire property rights of research carried out in universities and public laboratories (Gitelman and Kogut, 2003). Murray (2004) and Almeida et al. (2011) have gone further, stating that this social capital might have major repercussions on a firm's output.

H4: Companies experiencing difficulties in the search for knowledge and for partners for innovation are more likely to recruit PhDs.

2.5 Companies with uncertainty of the innovative products and services market recruit PhDs

Finally, one of the most important roles played by PhDs is the forging of a link between science and innovation. In their search for scientific knowledge, companies chase that knowledge which can be turned into goods and services. In firms increasing their competitiveness through cutting-edge technological knowledge, PhDs play a role in finding market use for scientific knowledge. As they are exposed to academic research, they have the advantage of being able to assess the potential

implications of recent breakthroughs in basic research from a commercial point of view, acting as gatekeepers in the processes of transfer and absorption of technological knowledge (Zellner, 2003). This context begs the question as to whether a company's market situation influences its recruiting of PhDs. To the best of our knowledge, the literature has undertaken no empirical analysis of the nature of this relationship. Although academic research has traditionally been thought to proceed in isolation from knowledge of the market, the arising of the entrepreneurial university has shed light on new roles for scientific staff (Lam, 2011; O'Gorman et al., 2008). In research on the mobility of PhDs, individuals have been found to prefer to follow a career in a firm when they have detected a commercial value for the results of their research (Crespi et al., 2007; Zucker et al., 2002ab). Indeed, studies in this field analyse patents (one of the most market-oriented instruments of knowledge protection) to determine mobility patterns (Fritsch and Krabel, 2012). According to O'Gorman et al. (2008) scientists recognize the commercial value of new knowledge when market-related knowledge is embedded in its research context or when they develop external contacts with those who possess knowledge of the market. For this reason, it has been pointed out that the recruitment of PhDs may depend on the nature of the research carried out and its proximity to the product market (Beltramo et al., 2001). In the present study, we propose an exploratory hypothesis to ascertain whether a firm's market situation can influence PhD recruitment. In general, it has been shown that their mobility is mainly directed into firms in high-technology sectors whose growth depends on research activities with unknown outcomes. As a result, it may be expected that firms with a major degree of uncertainty concerning the innovative goods and services market are more likely to recruit PhDs.

H5: Firms with a high degree of uncertainty of the market are more likely to recruit PhDs.

3. Data, Method and Variables

The data used in our analysis are those of the Panel of Technological Innovation (*Panel de Innovación Tecnológica – PITEC*) of the National Statistics Institute (*Instituto Nacional de Estadística – INE*) and the Spanish Science and Technology Foundation (*Fundación Española para la Ciencia y la Tecnología – FECYT*). Since 2003 the Panel has been gathering information on the innovation activities of around 11,000 Spanish firms belonging to two subpopulations: one of firms with over 200 employees and one of firms with R&D expenditures. The representative nature of the two groups is, respectively, 73% and 60% of Spanish companies. The data used in this study are from the 2009 survey. For the analysis, the sample was limited to companies reporting innovation expenditures. A total of 6068 firms were analysed, 1115 (18.38%) of which stated that they had recruited PhDs to carry out R&D activities.

To analyse the factors influencing companies' propensity to employ PhDs we used a Probit model and estimated the marginal effects to ascertain the relative importance of the explanatory variables. In this model, the dependent value took the value of 1 if the company reported having PhDs among its R&D staff in 2009. Variables included indicators of companies' characteristics and their geographical and competitive situation, along with indicators of their innovation activity and the difficulties to innovation. They were chosen in the light of the literature that analyses the mobility of academic researchers to firms from different levels of analysis

(Agarwal et al., 2009; Auriol, 2010; Beltramo et al., 2001; Cruz-Castro and Sanz-Menéndez, 2005; García-Quevedo et al., 2012; Herrera et al., 2010)¹. As indicators of a firm's experience and capacity to obtain resources, we have used size (logarithm of the number of employees) and its age (a dummy variable indicates whether the firm aged 5 years or less). In addition, a dummy variable took the value of 1 if the firm was situated in a central region of Spanish Innovation System such as Madrid, Catalonia, Basque Country or Navarre, where 70% of the national R&D expenditure is concentrated and more financial and human resources are attracted to innovation than in other regions (Herrera and Nieto, 2008).²

Among indicators of innovation activity we included the sector of activity. Three dummy variables were given the value of 1 if the firm belonged to a high- or medium-technology manufacturing sector or the high-technology service sector (using Eurostat's NACE Rev. 2 classification). In the same group of indicators we included three dummy variables to indicate whether the firm had received public funding in the past, cooperated with universities or considered that the lack of qualified staff was an important setback to innovation activities in the period 2007-09.

To test Hypothesis 1, we included a dummy variable that was given the value of 1 if the firm answered affirmatively to the question whether it carried on any type of biotechnological activity.³ To test Hypothesis 2, concerning failure of the innovation activity we included two dummy variables reflecting the abandonment of

¹ As explained, much of this literature does not empirically analyse cause-effect relations between company characteristics and the recruiting of PhDs, but does take into account these variables to define the profile of the contracting firm and ascertain the labour market for PhDs in the private sector.

² Location was determined on the basis of R&D expenditure and the number of employees engaged in these activities that firms had in different autonomous communities, so, for example, it was decided that a firm was located in Madrid if its R&D expenditure and number of employees was greater here than in any other region.

³ Activities based on sciences and technologies applied to living organisms or compounds obtained from them. These activities include bioinformatics and nanobiotechnology.

innovation activities in the period 2007-09. The first one took the value of 1 if the activities or projects were abandoned in the design stage and the second, the value of 1 if those activities or projects were abandoned once started. To test Hypotheses 3, 4 and 5 we used information on the value firms gave to the factors impeding their innovation activities or projects. We gave each factor the value of 1 if the firm considered it important and 0 if not.⁴ The survey affords no annual information on the importance of these factors but a global value for the 3-year period 2007-09. As a result, we observe the importance and persistence in the time period of these difficulties to innovation. To test Hypothesis 3, concerning financial difficulties, we included three factors: the firm's lack of funds, the lack of external funding and the high cost of innovation. To test Hypothesis 4, concerning the search for knowledge and innovation partners, we included 2 factors: the lack of information on technology and the difficulty in finding innovation partners. Finally, in the case of Hypothesis 5, concerning the market, the factors included were a firm's situation in a market dominated by established companies, the uncertainty enshrouding the demand for innovative goods and services and the lack of market information.

4. Results and Discussion

Table 1 shows the results of the Probit model and the marginal effects. At first sight, the results confirm those obtained in empirical studies at the firm level (García-Quevedo et al., 2012; Herrera et al., 2010) and afford empirical evidence of some of the ideas presented in the literature analysing the mobility of scientists into the private

⁴ In the original survey companies had to evaluate each innovation-limiting factor according to its degree of importance: high, medium, low or nil. In our study the values relating to these factors took the value of 1 if the company stated that the factor in question was of high or medium importance.

sector. Bearing in mind the structural characteristics of the firm, the study reveals that the variables: size, age and location had a positive and significant influence on the firms' propensity to recruit PhDs for their R&D activities. In the literature the influence of age and size is not clearly defined. According to Zucker and Darby (2007) the employment of scientists can occur in large incumbent firms seeking to adopt new technologies or in small new ones created around star scientists. The results of the study seem to support this idea, but the estimation of the marginal effects reveals that age could be relatively more important than size. A change in the variable age (firms aged 5 years or less), *ceteris paribus*, would increase the propensity to employ PhDs by 6 percentage points as opposed to the 2 points of a change of the variable size size. Zucker's studies extensively document the importance of scientific discoveries in the creation and transformation of young firms (Darby and Zucker, 2001; Zucker et al., 1998b). In sectors of high technology, young firms may arise around a radical idea based on scientific knowledge embodied in highly qualified human resources (Zucker et al., 1998b) or may adopt a talent recruitment strategy to overcome initial constraints on innovation (Rao and Drazin, 2002). The location of the firm in a technological region has the same relative importance as age. Many of the empirical studies on the effects of the mobility of researchers were carried out at the geographical level, especially to analyse the situation of knowledge flow [See Lenzi, (2010) for a review]. Stephan's studies (Stephan, 2006; Stephan et al. 2004) revealed there to be geographical concentrations of PhDs in highly technological regions and that PhDs working in firms habitually move to these regions rather than remain in the places where they did their doctoral studies.

The indicators of firms' innovation activity give us more detailed information of the profiles of companies requiring PhDs. We found that the activity sector was a major factor determining recruitment, high-technology manufacturing and service firms being especially likely to employ PhDs. Such companies sell products and services requiring more technological knowledge and are more likely to hire highly qualified staff to develop their R&D. Additionally, these companies need to widen their knowledge base and find recruitment a tool for this. The study also shows that public funding and prior cooperation with universities had a significant and positive influence on PhD recruitment. Studies of the effect of innovation policies have shown that obtaining public funding is positively linked with recruiting R&D staff (Busom, 2000; Lerner, 1999). As a result, it could be interpreted that firms receiving public funding are more likely to hire scientists. A change in this variable, *ceteris paribus*, would increase this likelihood by 8 percentage points. The study shows that a change in past cooperation with universities would, *ceteris paribus*, significantly increase it by 15 percentage points. This result has two possible explanations. Firstly, in the processes of cooperation with universities, PhDs play an important role because they are in a better position to understand the methods of cutting-edge scientific research used in universities (Ding, 2011). Secondly, although mechanisms exist to regulate the labour market of scientists (i.e., reputation, productivity, membership of networks), prior relationships with universities help to lessen uncertainty in this field (Lanciano-Morant and Nohara, 2006).

The study also reveals that firms considering the lack of qualified staff as an important setback to developing innovation activities were less likely to hire PhDs. It is important to point out that this recruitment raises the cost of innovation activity and that its function hitherto has been linked with the firm's technological track record

(Herrmann and Peine, 2011). Although the activities of company management demand a higher level of qualification, the number of employees involved in them is low. The data used here do not let us establish what level of qualification firms demand, so we interpret here that the firms in the sample may be interested in qualified staff with a different background, perhaps more oriented to R&D activities, like technical staff.

The study also contributes empirical evidence to confirm the hypotheses formulated and detects that new roles for scientific staff may influence the decision of companies to employ doctors or not. For example, companies declaring an involvement in activities based on science and technology applied to living matter, like biotechnology, bioinformatics and nanobiotechnology (that is, areas close to basic research) showed a greater propensity to employ PhDs. As a result, **Hypothesis 1** is confirmed. The estimation of marginal effects shows that a change in the variable biotechnology, *ceteris paribus*, would increase this tendency by 38 percentage points. As a result, this is definitely the most important variable in the model. Firms in biotechnological sectors need to continually renew their technological knowledge base and for them academic research is one of their main sources of knowledge (Ding, 2011; Deeds et al., 2000). In this regard, the literature gives evidence that for years scientists have played a major role in shaping the formation and transformation of biotechnology-based industries (Darby and Zucker, 2001; Zucker et al., 2002a).

The study also reveals that the likelihood to hire PhDs rises significantly when the company has abandoned innovation projects. This propensity, *ceteris paribus*, would increase by 4 percentage points if the projects were abandoned at the conception stage, and 5 points if they were abandoned after they were started. This confirms **Hypothesis 2**. Companies could need to employ doctors to overcome failure

and guarantee continuity and the development of their innovation activities. PhDs can be the instigators of these processes and their knowledge and acquired skills may be of key importance at different stages of them. The study reveals that it is in the primary stages that they could influence most. Agrawal (2006) remarks that knowledge generated in universities reaches firms in an embryonic state and has to be developed for commercialization. In these processes, the employment of the researcher is of key importance as during the invention process they acquire a unique latent knowledge of the technology that determines the transformation of scientific knowledge into products for the market.

When we analysed the factors concerning a firm's financial difficulties, we found that the lack of external funding had a significant positive influence on the recruiting of PhDs, thus confirming **Hypothesis 3**. In recruiting scientists, firms may find the support needed to seek external funding with other agents. This can happen in at least two ways. Firstly, firms may be more successful when they take part in subsidized research projects (Corolleru et al., 2004) while, secondly, their scientific activity is legitimized in the eyes of stakeholders and may attract more resources (Rao et al., 2008). In this regard, Darby et al. (2004) showed that recruiting star scientists could increase a firm's market value. We also found that firms attributing importance to the difficulty of finding partners for innovation were more likely to employ PhDs, which confirms **Hypothesis 4**. During their postgraduate studies, doctoral students form links with universities and scientific communities. Companies may feel motivated to recruit doctorate holders not only to access the human capital that they possess but also their social capital, which could give firms access to new sources of knowledge and research legitimacy in scientific communities (Almeida et al. 2011; Tzabbar, 2009).

Finally, the study confirms that the market situation can influence firms' tendencies to employ PhDs (**Hypothesis 5**). Companies attributing importance to uncertainty in the demand for innovative goods and services as a setback to innovation activity significantly lowered their tendency to employ PhDs. These firms' innovation activity may not be based on research activities with potentially uncertain results. Our results support the idea that companies with a strong science base (firms in the high-tech and biotechnology sectors) want more PhDs and they may choose relatively riskier R&D projects. These companies achieve more breakthroughs and so are more prone to great successes or failures than others (Darby et al. 2004). As a result, it would seem natural for companies adverse to risk, have less propensity to hire highly qualified scientific and technological staff.

(Table 1 here)

5. CONCLUSIONS

In this study we propose an exploratory analysis of the factors determining firms' employment of PhDs. In general, the literature analysing their mobility does so at the individual level, concentrating on what motivates a researcher to seek work opportunities in the private sector. At the company level, studies are scarce, and in general there is no clear understanding of the factors motivating firms' recruitment of PhDs.

The analysis of the hiring of PhDs is important because it allows us to define their labour market, their importance in the processes of knowledge transfer and their

role in firms' innovation activity. In this paper we define the recruitment of PhDs as a function of opportunities that firms have to appropriate their knowledge and skills. Traditionally, it has been thought that PhDs are only employed to generate and absorb technological knowledge. Nevertheless, there is literature that reveals that they can assume other roles in the innovation process, all derived from their PhD training and their research experience.

Despite the primarily exploratory intent of this study, the results confirm two major suppositions. Firstly, a large number of structural characteristics of firms influence the recruitment of PhDs, which means that a recruiting firm has a certain profile, and that the propensity to hire doctors among all firms in the economy is not even. Secondly, the study confirms that companies are motivated to contract PhDs when they are faced with a greater number of setbacks to their innovation activity. That is, companies would recognize the use or role of PhDs in different aspects of the innovation process.

Regarding company profile, we found that size, age and location in a technological region, the activity sector, obtaining public funding in the past and cooperation with universities significantly increased firms' propensity to employ PhDs. A company profile is thus defined that coincides with the one found in the literature. It should be pointed out that the variables relative to the activity sector and past cooperation with universities were those of greatest importance within this group of variables. Firms in such sectors as high technology require more technological knowledge and consequently more human resources in science and technology. In addition, in universities, these firms find a major source of knowledge and can make use of cooperation with them to reduce information in the PhDs' labour market. Unlike other studies, ours included as a control measure a variable expressing the

importance given by firms to the lack of qualified staff for the development of their innovation activity. The study reveals this variable to have had a significant and negative influence on the tendency to employ PhDs, although its importance relative to other variables in the model was limited. This leads us to conclude two things: 1) there are factors with a greater influence on a firm's decision to employ PhDs (e.g., the orientation of research and the need for scientific knowledge) and 2) the companies in the sample may be looking for staff with different kinds of qualifications for the development of their innovation activity.

In this study we formulated a set of hypotheses to obtain in-depth knowledge of why firms employ PhDs. In the first place, it presents clear evidence that PhDs have an important role in companies involved in activities close to basic research, as they are more likely to employ doctorate holders to facilitate access to scientific knowledge. The estimates made allowed us to establish that this is perhaps their most important reason for doing so. Moreover, the literature has shown that scientists have played a major part in the development of science-driven industries. It is, however, in the analysis of the factors hindering research where this study contributes important findings to the literature analysing the movement of PhDs into the private sector. It revealed that firms that had suffered failures or had abandoned innovation projects and activities were more likely to take on PhDs. Their role in the process of overcoming difficulties in the transformation of scientific knowledge into marketable products and services is therefore recognized. The knowledge of technology and the skills acquired during their research careers put PhDs in a position to propose solutions to a wide range of problems and companies could find in their recruitment a mechanism to guarantee success and the continuity of the innovation process.

The results of the study also show that doctors can play an important part in companies with difficulties in finding external sources of funding for innovation. Companies whose growth depends on scientific progress take on risky R&D projects with a high probability of success or failure. These companies have to persuade stakeholders of the legitimacy of their research activity in order to attract resources and, to this end, take on expert staff. In addition, these companies may benefit from the skills that researchers have developed to access public funds through research projects. We also found that companies experiencing difficulties in finding research partners are more likely to employ PhDs. During their PhD studies and research careers, they develop social capital that can assist companies in the creation of strategic alliances with other researchers, universities and technology centres. These alliances are not only essential for accessing scientific knowledge but also for detecting technological opportunities and resources outside the company.

Finally, although the literature establishes no clear connection between the goods and services market and the recruitment of doctors, our study shows that companies that consider a high level of uncertainty in the market for technological goods and services to be important are more likely to contract PhDs. The explanation is deduced clearly from the company profile defined in this study and others. Firms that employ PhDs are heavily orientated to the development of research activities focused on breakthroughs, the market for which may be uncertain. Indeed, many of these companies are created around completely new ideas in the product market and, as a result, it seems reasonable to conclude that firms averse to running risks do not get involved in activities requiring the employment of scientists.

This study has important implications for firms, PhDs and innovation policies. The analysis of the labour market for doctors is important because academia is

ceasing to be the main source of employment for them (Cruz-Castro and Sanz-Menéndez, 2005; Lee et al., 2010; Masso et al., 2009). Employment openings are becoming rarer and rarer in academia, which obliges doctors to seek work in industry (Lanciano-Morandat and Nohara, 2006), probably in firms where doctoral studies have little relevance. Although our study shows that the demand for PhDs lies mainly in firms in fields close to basic research, doctorate holders have been acquiring skills and key roles over time for the continuity and development of the innovation process which could be transferable to other sectors of the economy. It is incumbent on firms to take advantage of these new roles and skills of PhDs, many of which are embodied and cannot be imitated by other firms. In this context, universities and public agencies should make a greater effort to favour the mobility of PhDs into the private sector, among others, bringing academic research into closer contact with industry. For this, it is of major importance that future lines of research analyse the factors influencing the process of integrating scientific knowledge into a firm's knowledge base and organizational routines.

Finally, it is important to point out that the conclusions of this study must be interpreted with caution, owing to the nature of the data used in the period studied. The surveys available for analysing the mobility of PhDs offer no information on the conditions of their mobility or the year when they join firms. Access to primary information from firms or public mobility programmes could improve knowledge of the contribution of scientific staff to firms, as well as the barriers to their access in the private sector. Access to that information should be ongoing in order to widen the time horizon of research and detect other factors influencing mobility.

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Table 1. Results of the probit model estimations and marginal effects

Variables	Coefficient	M. E.
High-tech manufacturing sector	0.49 ***	0.14 ***
Med-tech manufacturing sector	-0.05	
High-tech service sector	0.34 ***	0.09 ***
Biotechnology activities	1.15 ***	0.38 ***
Firm size (log number of employees)	0.09 ***	0.02 ***
Recently set-up firm (< 5 years)	0.25 ***	0.06 **
Firm located in a technological region	0.26 ***	0.06 ***
Cooperation with universities (t-1)	0.55 ***	0.15 ***
Public Funding (t-1)	0.33 ***	0.08 ***
Abandoned innovation projects in design phase	0.18 ***	0.04 ***
Innovation projects abandoned once initiated	0.18 ***	0.05 ***
Internal financial constraints	-0.07	
External financial constraints	0.15 **	0.03 **
Innovation costs too high	-0.06	
Lack of qualified personnel	-0.10 **	-0.02 **
Lack of information about technology	-0.01	
Lack of information about markets	-0.04	
Difficulty in finding value R&D partners	0.08 *	0.02 *
Market dominated	0.62	
Uncertain demand	-0.10 **	0.02 **
N	6068	
Number of firms hiring PhDs	1115	
Number of firms not hiring PhDs	4953	
Log likelihood	-2390.86	
Pseudo R ²	0.17	
Correctly classified (%)	83.64	

M.E. = Marginal effects

*** Significant at 1%, ** Significant at 5%, *Significant at 10%.