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PhD careers in Spanish industry: Job determinants in manufacturing versus non-manufacturing firms

Liliana Herrera *, Mariano Nieto

Departamento de Dirección y Economía de la Empresa, Facultad de Ciencias Económicas y Empresariales, Universidad de León, 24071 León, Spain

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ABSTRACT

Recent studies undertaking an analysis of PhD careers have noted that academia remains the first choice employment sector; nevertheless, they also reveal an excess of PhD holders for the academic sector and show that industry is increasing as an important employment source for these human resources. In this study, the factors that shape a PhD's decision to pursue a career in the private sector are analyzed. The results reveal influences of not only academic factors but also personal characteristics and job requirements. This study also analyzes whether PhDs within the private sector show different career patterns. The results confirm the existence of a different profile in the case of PhDs working for manufacturing firms. Differences were detected with respect to knowledge areas, the type of research undertaken during PhD training, the sources of received grants and the minimum level of study required to perform the job. As a result, the private sector should not be considered a homogeneous work place for doctorate holders.

1. Introduction

The incorporation of PhD holders into firms has increased recently due to the recognition that scientific advancement can have an important impact on industrial development and growth (Cohen et al., 2002). PhD holders can be used to search for and collect knowledge as well as to systematically test and evaluate the potential of new discoveries from a commercial point of view (Zellner, 2003). Studies have shown that PhDs convey not only scientific knowledge but also important skills that are useful for firms at different stages of the innovation process (Herrera and Nieto, 2015). These skills, which are acquired during PhD training and research trajectories, have been demonstrated to be suited to linking science to innovation (Beltramo et al., 2001), reducing the failure risk in the innovation process (Zellner, 2003) and connecting firms with knowledge networks (Dietz and Bozeman, 2005; Hess and Rothaermel, 2011; Murray, 2004). Studies have also found that scientists in firms have a positive and significant influence on the inputs and outputs of the innovation process (Zucker et al., 1998; Herrmann and Peine, 2011).

Despite the importance attributed to scientists in firms, academia has remained the referent sector for PhDs to work in. PhD graduates have frequently been trained to undertake a research career in academia and not in industry, and as a result, they are often unable to obtain value from their degree in the private sector (Mangematin et al., 2000). It has been shown that when firms hire scientists, problems can arise that are mainly derived from the integration of their scientific knowledge into the firm's knowledge stock. This integration may not be automatic due to the tacit nature of the embodied knowledge of academic researchers (Kessler et al., 2000) and the different knowledge production regimes that are present in academia and industry (Stern, 2004). While academic researchers tend to lean toward open science regimes and seek prestige together with the diffusion of their research results, firms often prefer to protect newly acquired knowledge. Academic researchers can also have a lower production rhythm (timing) compared with that present in industry, which requires intensive work focused on product-oriented projects and a constant battle against time to launch new products (Lee et al., 2010).

Academic career orientations are becoming a problem if one takes into account that academia has ceased to be the main employment sector for doctorates and that industry is actively increasing as an alternative source for the provision of labor (Cruz-Castro and Sanz-Menéndez, 2005; Lee et al., 2010). It is widely known that the number of PhDs increases annually, and academia is unable to absorb all of the PhD laureates (Auriol, 2010; Auriol et al., 2013). This situation leads to at least two research questions: “What factors explain PhDs' pursuit of careers in the private sector?” and “Do different PhD career patterns exist within the private sector?”.

The literature regarding the factors that determine PhDs' careers has centered more on the study of career preferences in academia than in industry (Mora, 2001; Subramaniam, 2003). Studies examining PhD careers in firms are still scarce and bestow more weight on the academic

* Corresponding author at: Departamento de Dirección y Economía de la Empresa, Universidad de León, Campus de Vegazana s/n, 24071 León Spain.
E-mail address: liliana.herrera@unileon.es (L. Herrera).

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factors explaining PhD mobility to firms (Mangematin, 2000; Thune, 2009). Thus, information relative to firms hiring PhDs has not been analyzed exhaustively. This gap raises important problems if one takes into account that information about the PhD labor market is critical for policy makers designing PhD mobility programs or for universities attempting to create links between industry needs and their research programs. In general, studies analyzing PhDs' careers in firms have considered the private sector as a homogenous work place without taking into account the well-known heterogeneity of firms, which suggests that not all firms are attractive work places for PhD holders (Mangematin, 2000; Zucker et al., 2002b; Dany and Mangematin, 2004; Recotillet, 2007; Roach and Sauermann, 2010; Fritsch and Krabel, 2012). Recent studies provide arguments supporting the existence of different career patterns in the private sector. These arguments are related to PhDs' competences and skills (Lee et al., 2010), the broad heterogeneity of PhDs (Rothaermel and Hess, 2007; Baba et al., 2009; Toole and Czarnitzki, 2009; Faems and Subramanian, 2013) and the different requirements for jobs (Mertens and Röbken, 2013).

This study has analyzed PhD careers in the private sector. Due to the important role of PhDs in the scientific knowledge transfer processes to industry, in this study, the private sector has been considered to consist of manufacturing and non-manufacturing firms. The first part of the analysis is focused on establishing the factors that determine PhDs' propensity to pursue a career in the private sector. The second part focuses on determining whether PhDs within the private sector show different career patterns. To undertake these analyses, a sample of Spanish PhD holders has been used. Spain is an interesting case to study because it is facing important problems with regard to demand changes in its PhD labor market. PhDs have traditionally been employed by the public sector, but the current economic crisis is forcing changes. This study finds that approximately 80% of the PhDs surveyed had been employed by either the government or by the higher education sector. In addition, compared with other European countries, Spain has scarce PhD production in science and engineering (S&E) and scarce PhD employment in firms. Overall, this situation shows that the Spanish government must expend important effort to reinforce the mechanisms that facilitate scientific knowledge transfer to industry through PhD mobility programs.[1]

This study uses data that was obtained from two waves of the Spanish survey Human Resources in Science and Technology (HRST). The HRST survey collects information regarding the PhDs' situation before and after obtaining a job in the private sector. Consequently, this study analyzes the factors that determine actual PhD mobility into the private sector and does not consider career preferences for this sector.

2. PhD careers in industry: a literature review

Scientific knowledge is widely recognized to be highly important for technological advancement and economic development (Gibbons and Johnston, 1975; Mansfield, 1991; Rosenberg, 1992). Firms that rely on science can obtain multiple advantages that include, among other things, speedy access to new discoveries (Stern, 2004). To take advantage of this knowledge, firms are required to recruit scientists who are capable of producing it. Although their recruitment is traditionally justified in the early stages of the innovation process, recent studies have demonstrated that scientists can also play important roles downstream in this process (Herrera and Nieto, 2015). Thus, scientists' roles in firms are not only linked to exploration but also to knowledge exploitation activities (Rothaermel and Hess, 2007). The literature has also recognized that PhDs possess different types of knowledge and skills that go far beyond the general background of their discipline and that can be useful to firms in carrying out their different activities (Zellner, 2003; Luo et al., 2009; Teirlinck and Spithoven, 2013). According to Zellner (2003), these non-specific knowledge skills are related to capabilities to formulate, structure and solve a diverse range of problems. The scientists analyzed in his study recognized that these skills were of more value for work in the commercial sector than those derived from their specific knowledge. As a result, these new roles and skills have opened the possibility for PhDs to find jobs outside of the science-driven industries, thus increasing the labor market complexity in the private sector.

Studies that have analyzed the determinants of PhDs' careers in the private sector are scarce and have traditionally focused on samples of doctoral students. Recent studies cast doubt on the analysis of PhD student preferences as the most suitable method for understanding the complex processes leading to a PhD's career choice. According to Sauermann and Roach (2012), PhD students manifested different interests at the beginning compared with the end of their graduate program; consequently, it is extremely difficult to forecast exactly what sector they will end up working in. Nevertheless, the literature has advanced and recognized that academic and non-academic factors exist that exert an influence on PhDs' early interest to work in the private sector.[2]

In connection with academic issues, the knowledge field has primarily been analyzed along with the grants received, the collaborations established with the private sector and the duration of the PhD training. Among these factors, the knowledge field ranked as perhaps the most important factor. Different authors seem to agree that doctorates who worked in industry had carried out PhD training in areas whose commercial applications are more visible, such as science or engineering (Roach and Sauermann, 2010; Fritsch and Krabel, 2012; Sauermann and Roach, 2014). Studies have also established the impact of the research type that doctorates accomplished during their PhD training. For example, individuals who were more interested in applied research and development found a research career in established firms to be more attractive (Fritsch and Krabel, 2012). Conversely, individuals with a strong “taste for science” corresponded with those with a strong preference for research freedom, a high degree of publishing ability and a desire to conduct basic research, and these scientists preferred to follow careers in academia as opposed to careers in industry (Roach and Sauermann, 2010).

Studies have also established a link between the PhD training grants received and the subsequent employment sector (Mangematin, 2000; Dany and Mangematin, 2004; Cruz-Castro and Sanz-Menéndez, 2005; Thune, 2009). PhD graduates with grants found it particularly difficult to obtain a private sector job (Mangematin et al., 2000). Nevertheless, if financing had been obtained through university–company collaborations, then the private sector partnership increased the possibility of obtaining a permanent position in the industry (Mangematin, 2000; Thune, 2009). A persistent idea in the literature reckons that the candidates who are most appreciated by the private sector are usually derived from laboratories or departments that maintain collaborative relationships (Dany and Mangematin, 2004; Recotillet, 2007). These relationships significantly reduce job market uncertainty

[1] The Spanish National Program called “Torres Quevedo” is a government initiative to encourage PhD mobility to research centers and firms. Approximately 295 PhD holders participated in this program in 2013. To the best of our knowledge, no recent studies have evaluated the impact of this program. The study by Cruz-Castro and Sanz-Menéndez (2005) presented some results of this mobility program.

[2] Studies on PhD careers in the business sector have mainly been undertaken in Europe. France comprises one of the most analyzed cases (Mangematin, 2000; Mangematin et al., 2000; Recotillet, 2007; Dany and Mangematin, 2004), followed by the USA (Zucker et al., 2002a; Roach and Sauermann, 2010), Germany (Fritsch and Krabel, 2012) and Spain (Cruz-Castro and Sanz-Menéndez, 2005).

and mostly prevail in industries that are the most strongly dependent on scientific knowledge. In this regard, Recotillet (2007) showed that the intensity of the relationship with the firm was an important factor in predicting doctorates' career paths. Studies have also established that departments or research institutes' norms on the subject of work with industry had a positive influence on career orientation (Roach and Sauermann, 2010) as well as on peer opinions about the attractiveness of private sector work (Fritsch and Krabel, 2012). Aschhoff and Grimpe (2014, p. 379) found, in the instance of biotechnology scientists in Germany, that a scientist's involvement with the private sector increased with the orientation of the scientist's department toward the industry, especially in the case of younger scientists. Finally, the duration of doctoral studies has also been found to be a determinant. Individuals who completed their doctoral degrees in less time had a higher chance of finding jobs in firms (Mangematin, 2000).

With regard to non-academic factors, the literature is generally restricted to the appraisal of demographic variables to identify the specific characteristics of PhD holders. These variables record data on gender, age and marital status (see Mangematin, 2000; Bornmann and Enders, 2004; Cruz-Castro and Sanz-Menéndez, 2005; Recotillet, 2007). Overall, studies have not obtained significant results from the analysis of these variables. Among them, gender and marital status have been perhaps the most studied, given that they are of interest for monitoring the advancement of women in scientific careers (Duberley and Cohen, 2010) while allowing the ability to control for the fact that the academic areas that display high PhD mobility rates to firms (such as science & engineering) tend to have a high incidence of males. With respect to the above, it has been shown that female PhD holders maintain a higher unemployment propensity (Cruz-Castro and Sanz-Menéndez, 2005) and that married women display different patterns of mobility compared with married men. According to Sumell et al. (2009), it is more likely for married female PhD holders not to leave the region where they undertook their PhD training. With regard to age, previous studies have established a non-significant effect (Cruz-Castro and Sanz-Menéndez, 2005; Zucker et al., 2002a), or else contradictory tendencies have been uncovered. For example, Fritsch and Krabel (2012) showed that while older PhD students assessed private sector work as an attractive option, this attractiveness decreased with a senior researcher's age. Enders (2002) recognized that age was an important element when PhDs opted for a career in higher education and research outlets, as these sectors usually tend to reward youth.

Non-academic factors have so far been scarcely analyzed within the literature, although they could be crucial factors in clarifying a PhD's decision to pursue a career in the private sector. Some studies have introduced contextual factors into the analysis, such as firm location. Location has gathered increasing interest in view of the high regional concentration of firm innovation activities and the importance of the proximity factor in the knowledge transfer process. Studies considering firm locations as a private sector PhD career predictor have demonstrated that firms in regions with a high concentration of innovation activity can attract more scientists and that individuals do not always find a job in the places where they obtained their PhD training (Zucker et al., 2002b; Stephan et al., 2004; Sumell et al., 2009).

In general terms, the literature that has analyzed PhD careers in the private sector has not taken into account information relative to the firms. This study analyzes whether a firm's activity sector could possibly be a factor that influences PhDs' decisions to pursue a career in the private sector. Firms in the manufacturing and services sectors compose the private sector, and in many economies, the importance of the service sector is increasing as well as the number of scientists and engineers working in it. As a result, it would not be surprising to find that a firm's activity sector has an influence on PhDs' career choices. At least three arguments exist that support this idea. The first is related to a PhD's skills and competences. Lee et al. (2010) noted that several PhD competences exist that may be more or less relevant to different career types. For instance, while PhDs employed in technical positions in the manufacturing sector perceived "general knowledge of the PhD subject area" to be of higher value for their jobs, PhDs employed outside of conventional technical occupations (including the services sector) gave more value to the "general analytical skills" they obtained during their PhD training. Because employment outside of the conventional technical occupations has become the predominant career type, PhDs commonly have to choose between jobs that allow them to make use of either their specific knowledge skills or their non-specific knowledge skills (Zellner, 2003). The second argument is related to scientist heterogeneity and suggests that not all economic sectors are equally attractive work places for PhD holders. The literature has established that many different types of scientists work in firms and that their heterogeneity has an impact on the firms' innovation outputs (Furukawa and Goto, 2006a, 2006b; Rothaermel and Hess, 2007; Baba et al., 2009; Toole and Czarnitzki, 2009; Faems and Subramanian, 2013). Scientists' typologies have been established by taking into account 1) research productivity, i.e., star versus non-star scientists (Zucker et al., 2002a, 2002b; Subramanian et al., 2013); 2) embodied knowledge heterogeneity (Herrmann and Peine, 2011; Subramaniam, 2012); 3) a "taste for science" (Roach and Sauermann, 2010); 4) proximity to firm knowledge (Tzabbar, 2009; Tzabbar et al., 2013); and 5) the researcher's scientific or technological orientation (Baba et al., 2009). These typologies are not only linked to the knowledge area, they are also linked to personal preferences and could constitute determinants when individuals are seeking job opportunities in the private sector. A recent study by Bloch et al. (2015) examined employment sector PhD choices and differentiated between research and the non-research-based employment. The results revealed that the factors defining sector choice differed between these two groups, mainly because of the presence of self-selection based on employment sector "tastes" and preferences. In the same vein, a study by Sauermann and Roach (2014) analyzed how PhDs considering the pursuit of a career in industrial R&D made a trade-off between positions that allowed them to publish compared with positions that did not allow to them to publish. A third argument, which is currently less explored in the literature, is the existence of different labor conditions that could influence PhDs' choices to work in certain economic sectors. Mertens and Röbken (2013) showed that work in the production sector had a significant effect on PhD wages compared with the services sector, especially with regard to S&E areas.

In a first attempt to show that different career patterns exist in the private sector, this study distinguishes between jobs in the manufacturing sector and jobs outside of the manufacturing sector. In general, the literature has paid special attention to the role of scientists positioned in manufacturing firms as a result of their importance in new patent production. Firms in the manufacturing sector undertake more product-oriented projects, and it is expected that they will attract more PhD holders for at least three reasons. First, doctoral holders are considered to be useful for transferring scientific knowledge to the R&D industry. Much of the knowledge that has arisen from scientific breakthroughs has been characterized by its excludable nature. The high complexity and tacit dimension of this type of knowledge hinder its transfer; therefore, the active participation of those possessing it is required (Zucker et al., 1998). As a result, for firms working in the R&D industry it is of major importance to hire PhDs involved in the processes of technological knowledge generation and absorption, as they can incorporate into the company not only the most up-to-date knowledge but also the skills needed to reproduce and exploit it (Lee et al., 2010). In the second place, once knowledge has been gained, it is widely accepted that companies must overcome limitations pertaining to its transformation process into marketable products. Academic researchers can play important roles reducing the risks of failure at different stages of technological production and commercialization. According to Agrawal (2006, p. 64), during invention processes (trial and error), these human resources acquire a unique and complementary technology knowledge that enables them to recommend solutions to improve a product or to reduce manufacturing costs. Third and last, an important number of studies have demonstrated the importance of scientists in the manufacturing sector by way of the number of firm patents or increases in new product development (Baba et al., 2009; Deeds et al., 2000; Luo et al., 2009).

3. The Spanish PhD holder labor market

The number of PhD holders worldwide is increasing and along with them is their labor market complexity. According to data available from the Spanish National Institute of Statistics and the Ministry of Education, Culture and Sports, an average of 7783 doctoral dissertations were completed annually in the period 2000–2012 in Spain, reaching a maximum in 2012 with 10,504 dissertations. This figure shows a 65% increase with respect to the 6380 dissertations completed in 2000. Although the number of PhD holders has increased over the last decade, the total number of PhD holders in Spain remains low when compared with other countries. Data from the project "Careers of Doctorate Holders (CDH)" published in 2013 (in a joint project by the OECD, the UNESCO Institute for Statistics and EUROSTAT) revealed that in the last decade, the United States (708,900), Germany (360,460) and Switzerland (143,647) had the world's highest numbers of doctoral graduates, compared with 83,015 in the case of Spain.[3] These figures are astonishing and raise the question regarding whether it is necessary to increase the number of PhD holders in Spain, which had a population of 47 million based on a census in 2011. Answering this question is not easy because it involves making critical reflections not only about the importance of PhDs in a knowledge economy but also with respect to the real state of their labor market.

To analyze the Spanish labor market, a two-wave data set drawn from the Spanish Survey corresponding to the Human Resources in Science and Technology (HRST) was used in this study. The poll forms part of the general Science and Technology statistics plan, which is undertaken every three years; the surveys for 2006 and 2009 are the only samples available to conduct this investigation.[4] The survey gathers detailed information concerning PhD characteristics, PhD studies and current employment situations. The samples consisted of 12,146 and 3958 PhDs for the years 2006 and 2009, respectively. Table 1 displays a rough picture of the Spanish labor market for PhD holders, taking into account employment sectors and knowledge areas. The data show that the government and higher education sectors were the main employment sources of PhDs, with an almost invariable 81.07% and 81.62% of the surveyed individuals working in those sectors in 2006 and 2009, respectively. Cruz-Castro and Sanz-Menéndez (2005, p. 59) explained that in some Spanish research fields, "people expect difficulties in obtaining returns from the investment in a PhD; therefore, the cost of mobility becomes too high, and this contributes to enlarge the segment of waiting positions in the public sector". By knowledge areas, Table 1 shows that doctorates in the natural and medical sciences mainly found employment in the private sector and government departments, agencies and public bodies, while doctorates in engineering and technology mainly found employment in higher education. Focusing on the private sector, the figures show that the distribution of PhD holders by area is quite similar to that displayed by government (see Table 1). Only two differences were detected in connection with the higher education sector, which employed more engineering and social sciences PhDs compared with the other sectors.

This PhD labor market framework changed over recent years because government and higher education employment mainly depend on available public spending, which has substantially decreased during the economic crisis period that started in 2008. To reduce this spending, the government's strategy has been to impose important employment restrictions in these sectors, thus considerably reducing the job opportunities for Spanish PhD holders. In this context, the private sector has emerged as a potential employment source. However, the HRST survey reveals an almost invariably low absorption capacity of highly skilled personnel in this sector. Table 1 shows that only 14.72% of the surveyed PhDs were employed in this sector in 2006 and 14.49% in 2009. These figures contrast sharply with those of other countries such as Denmark, Belgium and the United States, where "at least one out of three employed doctorate holders work in the business sector" (Auriol et al., 2013 p. 19). In addition, PhDs working as researchers in firms amounted to 33.88% in 2006 and 42.06% in 2009. As a result, most PhDs working in the private sector have endured research trajectory interruptions.

Focusing on PhDs' mobility to the private sector once they have concluded their doctoral studies, a total of 1176 and 406 PhD holders found employment in this sector in 2006 and 2009, respectively. By firm type, approximately 22.19% entered the manufacturing sector in 2006 and 25.37% in 2009. To establish which knowledge areas were in greater demand within the manufacturing sector, this study followed the knowledge area classification defined by Cohen et al. (2002), which has been widely used (see Abramovsky et al., 2009; Barge-Gil and Conti, 2013), to determine the public research contribution to industrial innovation. The authors identified the following areas with the highest contributions: biology, chemistry, physics, computer science, material science, medical and health science, chemical engineering, electrical engineering, mechanical engineering, and mathematics. A total of 70.92% and 73.89% of the PhDs employed in the private sector worked in those areas in 2006 and 2009, respectively. Due to its increased importance during the last decade, the field of biotechnology was considered a separate area of biology. Delving into the manufacturing sector, Table 2 presents the PhD distribution using Cohen's knowledge area and industry classification. The data are displayed for only 2006 because that year had a higher number of PhD holders incorporated into the private sector than 2009. The descriptive data were acquired by encouraging the PhD workers to describe their firms' activity using the Spanish National Classification of Economic Activities (CNAE-1993). The descriptive data tabulated by industry revealed that more PhDs were hired by the chemical, food and manufacture of electrical, electronic and optical equipment industries. Taking into account the knowledge areas, PhD laureates in chemistry, medicine and health as well as the biology areas were the holders who were most often employed by the manufacturing sector. Contrary to expectations, the engineering areas showed only moderate employment rates in these sectors. Only a handful of doctorates in computer science, mathematics and electrical engineering were hired. Focusing on the chemical industry, the data revealed that firms in this sector employed 61% of all of the hired PhD holders, but their degrees did not always pertain to the chemistry or chemical engineering disciplines. It is important to highlight that this sector is considered to be high-tech and is characterized by elevated firm heterogeneity; as a result, it is expected to absorb a greater quantity of scientists. The data also revealed that the textile and clothing industry as well as the leather and footwear industry did not employ any PhDs. Although the data remain scarce to speculate about the consequences of these mobility patterns or their origin, the descriptive analysis revealed two important problems in the Spanish private sector: low firm R&D activity and a scarce public research contribution to industry.

[3] This study does not delve into international comparisons because the CHD project reports very detailed information about PhD careers within the OECD area.

[4] Data for subsequent years were not collected, probably due to the economic crisis.

Table 1
PhD percentages by activity sector and knowledge area.

	Private sector		Government		Higher education		Private non-profit sector	
	2006	2009	2006	2009	2006	2009	2006	
PhD percentage	14.72	14.49	37.16	39.17	43.91	42.45	4,21	3.89
N	12,146	3958	12,146	3958	12,146	3958	12,146	3958
Knowledge area								
Natural sciences	33.45	36.06	23.73	28,24	31.06	34.96	34.50	45.45
Engineering and technology	10.51	11.32	4.96	3,48	13.30	11.85	11.11	9.72
Medical sciences	30.93	30.31	40.09	36.30	5.52	5.12	24.95	12.99
Agricultural sciences	4.31	2.96	4.49	3.68	3.54	2.86	3.12	3.25
Social sciences	12.25	12.02	13.51	14.12	31.02	28.47	13.84	15.58
Humanities	8.56	7.32	13.22	14.18	16.57	16.74	12.48	12.99
N	1788	574	4500	1551	5345	1679	513	154

4. Empirical model and variables

This study used data derived from the HRST survey, as already described in the previous section, for the years 2006 and 2009. The first part of the analysis focused on the private sector in general to determine which factors conditioned the propensity of doctorates to pursue a career in this sector. A sample of 10,575 surveyed PhDs was used, of which 1582 found a job in the private sector. In the second part, which considered a more restrictive sample of only those PhDs employed in the private sector, the analysis determined which factors condition careers in the manufacturing sector. In all cases, the dependent variable took the value of 1 if the PhD holder was working in a firm and had joined that firm at the end of her/his PhD training. As a result, this study analyzed real mobility to firms without taking into account PhD holder preferences. The first descriptive analysis showed that the dependent variables evidenced a strong positive skewness with an excess of zeros (85.04% of PhDs were not employed by the private sector); thus, a Generalized Linear Model (GLM) was applied. Hardin and Hilbe (2012) explained in detail why logit or probit models should not be used in circumstances where the responses do not contemplate a fairly equal number of cases scored as one compared with zeros. These authors concluded that for cases such as this study, log-log models provide a more robust estimation due to their asymmetric nature. For this reason, GLMs with a binomial family and a log-log link were used in this study. The GLMs were also chosen to control for over-dispersion, which can be an important problem in models with binary responses, as underestimations of the estimated coefficient's standard errors can be worked out, and consequently, non-significant variables can be revealed as having significant influences. GLMs provide Pearson's χ^2 or the deviance divided by the degrees of freedom. A Pearson's statistic close to 1 indicates that the models are not over-dispersed (they are well specified). The Huber-White Sandwich technique was used to correct for possible heteroskedasticity problems. The data evidenced no signs of multicollinearity, yielding the highest Variance Inflation Factor (VIF) a value of 1.32 (mean 1.08) for the pooled sample.

The explanatory variables were divided into three groups. The first group included factors related to the PhDs' training. Several dummy variables were incorporated to control for the different knowledge areas analyzed: biology, chemistry, physics, material science, medical and health science, chemical engineering, electrical engineering, mechanical engineering and biotechnology. Observations of the computer science and mathematics areas were not used in the analysis because the PhDs working in the private sector showed less than 1% participation in those areas with respect to the entire data set. To analyze the types of research activities, a dummy variable took the value of 1 if the PhD had carried out only technological development during PhD training. Other types of research (basic and applied research) were excluded, as the preliminary descriptive analysis showed that a large number of the PhDs responded that they had undertaken more than one research type (basic, applied or technological development), which generated difficulties in constructing reliable indicators. With the objective of controlling for PhD study length, a continuous variable measured the duration in number of years until the conclusion. Because previous research has established that the grants received to undertake PhD studies are a determining factor, three dummy variables were included that indicated whether the PhD student had obtained a grant from a national public administration, a grant from a foreign public administration or depended on family financing and loans.[5] It was not possible to establish from the survey whether the PhDs had received funding from firms.

A second group of variables encoded information regarding the job held. To establish whether the PhDs had moved on to positions that did not require university degrees, two variables provided detailed information regarding the minimal study level required to perform the current employment position. One dummy variable took the value of 1 if the required studies consisted of a technical training level (technical college diploma), while a second variable took the value of 1 if the required studies consisted of basic up to secondary studies. A continuous variable was also included to control for the number of months since the PhD study had concluded until work started (unemployment time). Third, analogous to other studies, the individual's age plus its squared value together with gender (1 if male) and marital status (1 if married) were also included. Finally, a dummy variable for time (1 if 2006) was included to control for potential time differences. Appendix 1 presents the dependent and explanatory variable descriptive statistics and correlations.

5. Results and discussion

Table 3 displays the GLM model results. Pearson's statistics with respect to all of the models were close to 1, indicating that the models were not over-dispersed. As noted previously, the general sample analyzed the propensity of conditioning factors for pursuing a career in the private sector (Models 1–4), while a restrictive sample analyzed the manufacturing sector career determinants (Models 5–8). Focusing on Model 1 (data for 2006 and 2009 were pooled), the results confirmed those that had previously been observed and described in the literature (Mangematin, 2000; Zucker et al., 2002b; Dany and Mangematin, 2004;

[5] Other sources of funding (used as a reference) were not included in the analysis: grants from firms, grants from private non-profit institutions, working as a teacher or personal resources.

Table 2
PhD percentages by manufacturing sector and academic discipline.

Manufacturing sectors	N	Bio	Chem	Phys	CompSc	MatSc	Med	ChemE	EE	MechE	Math	BioTc
Food industry	34	26.47	38.24	0.00	0.00	0.00	20.59	5.88	2.94	0.00	0.00	5.88
Wood and cork industry	4	0.00	75.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paper industry and products, printed matter and recorded media	6	16.67	33.33	16.67	0.00	0.00	16.67	0.00	0.00	16.67	0.00	0.00
Refined petroleum and nuclear fuel	7	0.00	57.14	0.00	0.00	0.00	0.00	42.86	0.00	0.00	0.00	0.00
Chemical industry	185	14.05	41.0	0.00	0.00	0.54	32.43	6.49	0.54	0.54	0.54	3.78
Manufacture of rubber and plastic materials	5	20.00	60.00	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00
Manufacture of other non-metallic mineral products	7	0.00	71.43	0.00	0.00	14.29	0.00	14.29	0.00	0.00	0.00	0.00
Metallurgy and fabrication of metal products	6	0.00	33.33	0.00	0.00	33.33	0.00	0.00	0.00	33.33	0.00	0.00
Manufacture of machinery and equipment	13	0.00	30.77	23.06	0.00	0.00	15.38	0.00	7.69	23.08	0.00	0.00
Electrical, electronic and optical equipment industry	17	5.88	29.41	29.41	11.76	0.00	0.00	17.65	5.88	0.00	0.00	0.00
Manufacture of transport equipment	14	0.00	21.43	14.29	7.14	14.29	0.00	0.00	14.29	28.57	0.00	0.00
Other manufacturing industries	3	0.00	33.33	0.00	0.00	66.67	0.00	0.00	0.00	0.00	0.00	0.00
Total	301	38	121	12	3	8	70	22	6	11	1	9

Recotillet, 2007; Fritsch and Krabel, 2012; Roach and Sauermann, 2010). In general, the knowledge area, the type of research carried out, the type of PhD funding and the length of the doctoral studies all showed a significant influence on PhD propensity to pursue a career in the private sector. The results showed that individuals with doctoral studies in biology, chemistry, material science, medicine, chemical engineering and biotechnology all had a positive and significant probability of moving into the private sector. Unlike in other studies, PhD graduates in engineering areas such as electrical or mechanical did not show a significant propensity to pursue careers in firms (Mangematin, 2000). There are two reasons for this result: First, in Spain, the number of engineering and technology PhDs is rather low (less than half) compared with those in science, and second, a high quantity of engineering PhDs are employed in academia (see Table 1). The study also revealed that PhD holders who undertook technological development activities during their PhD training had a higher propensity to find a job in the private sector. Technological development is clearly an activity that is directed toward discovering the scientific knowledge required to produce practical applications and requires a researcher to be in close contact with the market and firms. This result confirms the arguments of Roach and Sauermann (2010), who noted that individuals who are more interested in applied work or development find a research career in an established firm to be more attractive. This study also found an interesting result in the case of PhD funding. While other studies have found support for the idea that students with grants tend to stay in academia (Mangematin et al., 2000), in the Spanish case, the results revealed that receiving a national or foreign grant from a public administration positively affects the decision to pursue a career in the private sector. Unlike in previous studies, in this case, family support and loans were considered to be financing sources, and they showed a significant and positive effect. The present study also verified that the length of PhD training is a determinant factor. Thus, long periods before the conclusion of doctoral study significantly reduced the propensity to obtain a job in the private sector. This result is in line with that obtained by Mangematin (2000), who concluded that individuals who had recently completed their PhD training had a higher propensity to obtain a job in the industry. Individuals taking a long time to complete their PhD studies, conversely, have a higher propensity to remain in academia because during that time, they are able to establish important associations with university research groups and departments.

This study also included two variables that gathered information on the minimum study level required for the job as well as a variable that recorded the number of months without employment after the completion of doctoral study. The results showed that with lower study level requirements for a job (for instance, not requiring a university degree), the propensity was higher for a PhD to occupy the job in the private sector. Stated in a different manner, PhDs in the current sample occupied positions that did not require a minimum level of university studies. This result is not surprising, as a similar outcome was obtained by Enders (2002) in the German case. The author in that study concluded that PhDs viewed the value of their training as rather low for the development of their professional career and their present job. In the same vein, data from the "Careers of Doctorate Holders (CDH)" project showed that in the case of Belgium, Spain, the Netherlands and Latvia, between 15% and 30% of doctoral graduates perceived that their jobs were not related to their PhD (Auriol et al., 2013). With regard to the time influence of being unemployed, the study revealed that long periods without employment increased the propensity to pursue a career in the private sector. Future research should establish what happens during these periods. For example, it would be interesting to determine whether jobs in the private sector are chosen after unsuccessfully attempting to enter into the academic world. The data also showed a significant influence of age and the squared term of age, thus revealing a nonlinear relationship between age and the propensity to pursue a career in the private sector. Fig. 1 graphically displays that with increasing age, career propensity in the private sector decreased.

The time dummy showed a negative and significant influence, thus revealing between-year differences. Models 2 and 3 display the estimations for the years 2006 and 2009.[6] The first difference was found with respect to knowledge areas. The study revealed that the demand for PhDs in certain knowledge areas was not consistent throughout time. This was the case for the chemical engineering knowledge area, which did not show a significant impact in 2009. The second difference was found with regard to the type of funding for PhD study. Grants obtained from the national government were not significant in 2009, while loans and family funding were significant. This result could be explained by the public budget reductions caused by the economic crisis starting in 2008. The last difference corresponded to age. This variable showed no significant influence for the group of PhD holders surveyed in the 2009 period, which likely indicates a tendency change in the labor market.

[6] Despite the year 2009 manifesting a lower number of observations by two-thirds compared with 2006, the proportions of PhDs pursuing a career in the private sector were quite similar (15.74% in 2006 and 13.10% in 2009). This result allows for some comparisons, although the results should be interpreted with caution. The difference in the number of observations by years could be explained by changes in the forms used to collect the data. The institution did not provide an explanation for this difference. As a result, any comment would only be speculation.

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Table 3
Generalized linear models.

	PhD careers in the private sector				PhD careers in the manufacturing sector			
	Pool	2006	2009	2009	Pool	2006	2009	2009
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Variables								
Knowledge area								
1 Biology	0.260[a]	0.273[a]	0.231[a]	0.225[a]	0.418[a]	0.336[b]	0.837[a]	0.780[b]
	[0.046]	[0.056]	[0.083]	[0.084]	[0.142]	[0.171]	[0.308]	[0.308]
2 Chemistry	0.502[a]	0.490[a]	0.529[a]	0.526[a]	1.147[a]	1.041[a]	1.509[a]	1.485[a]
	[0.049]	[0.059]	[0.088]	[0.089]	[0.146]	[0.173]	[0.292]	[0.291]
3 Physics	0.074	0.080	0.058	0.034	0.522[b]	0.481[c]	0.600	0.648
	[0.063]	[0.076]	[0.112]	[0.111]	[0.241]	[0.283]	[0.471]	[0.468]
4 Material science	0.499[a]	0.458[b]	0.554[c]	0.556[c]	2.134[a]	2.395[b]	1.747[c]	1.886[c]
	[0.174]	[0.214]	[0.292]	[0.301]	[0.752]	[1.068]	[1.029]	[1.120]
5 Medical and health science	0.339[a]	0.335[a]	0.350[a]	0.344[a]	0.555[a]	0.544[a]	0.783[a]	0.819[a]
	[0.037]	[0.044]	[0.070]	[0.071]	[0.125]	[0.154]	[0.254]	[0.255]
6 Chemical engineering	0.281[b]	0.287[c]	0.268	0.295	1.438[a]	1.408[b]	1.830[c]	1.848[c]
	[0.127]	[0.149]	[0.244]	[0.251]	[0.479]	[0.558]	[1.047]	[1.122]
7 Electrical engineering	0.065	−0.018	0.224	0.198	0.602[c]	0.367	1.054[c]	1.192[c]
	[0.086]	[0.106]	[0.151]	[0.149]	[0.317]	[0.415]	[0.541]	[0.576]
8 Mechanical engineering	0.184	0.147	0.318	0.287	0.388	0.536	−2.010[a]	−1.776[a]
	[0.125]	[0.139]	[0.284]	[0.273]	[0.436]	[0.496]	[0.250]	[0.308]
9 Biotechnology	0.598[a]	0.554[a]	0.702[a]	0.685[a]	0.872[a]	0.571[c]	1.846[a]	1.976[a]
	[0.106]	[0.123]	[0.206]	[0.205]	[0.259]	[0.303]	[0.612]	[0.680]
Type of research activity								
Only technological development	0.215[b]	0.159	0.345[c]	0.313[c]	−0.473[c]	−0.488	−0.382	−0.444
	[0.100]	[0.119]	[0.188]	[0.188]	[0.272]	[0.359]	[0.498]	[0.494]
Source of grant								
National grant	0.099[a]	0.112[a]	0.071	0.072	0.169	0.223[c]	0.026	−0.037
	[0.032]	[0.038]	[0.060]	[0.061]	[0.105]	[0.125]	[0.220]	[0.222]
Foreign grant	0.240[c]	0.217	0.340	0.361	0.325	0.535	−0.415	−0.606
	[0.136]	[0.156]	[0.281]	[0.284]	[0.425]	[0.474]	[0.918]	[0.864]
Loans or family funding	0.105[b]	0.080	0.158[b]	0.165[b]	−0.491[a]	−0.642[a]	−0.428	−0.454[c]
	[0.044]	[0.053]	[0.079]	[0.080]	[0.143]	[0.187]	[0.273]	[0.277]
PhD training length (years)	−0.017[a]	−0.015[b]	−0.021[b]	−0.022[b]	−0.017	−0.033	0.067	0.073
	[0.006]	[0.007]	[0.010]	[0.011]	[0.021]	[0.026]	[0.043]	[0.045]
Minimum study level required for current job								
Diploma	0.262	0.222	0.548	0.524	−0.144	0.024	−3.323[a]	−3.255[a]
	[0.175]	[0.190]	[0.495]	[0.488]	[0.561]	[0.580]	[0.387]	[0.413]
Pre-university studies	0.692[a]	0.705[a]	0.653[c]	0.659[c]	−0.498[c]	−0.679[b]	0.182	0.387
	[0.155]	[0.173]	[0.347]	[0.346]	[0.293]	[0.340]	[0.859]	[0.910]
Unemployment time (months)	0.038[a]	0.043[a]	0.027[a]	0.027[a]	0.037[b]	0.036[c]	0.055	0.054
	[0.005]	[0.006]	[0.010]	[0.010]	[0.016]	[0.019]	[0.036]	[0.036]
Age	−0.053[a]	−0.059[a]	−0.030	−0.037	0.050	0.023	0.458[b]	0.480[b]
	[0.016]	[0.019]	[0.033]	[0.033]	[0.060]	[0.066]	[0.193]	[0.194]
Age2	0.001[a]	0.001[a]	0.000	0.000	−0.001	−0.000	−0.006[b]	−0.006[b]
	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]	[0.002]	[0.002]
Female	0.025	0.022	0.033	0.028	−0.149	−0.218[c]	0.019	0.037
	[0.028]	[0.034]	[0.052]	[0.052]	[0.096]	[0.114]	[0.203]	[0.204]
Married	0.020	0.005	0.055	0.049	−0.064	−0.131	0.228	0.206
	[0.030]	[0.036]	[0.055]	[0.056]	[0.099]	[0.118]	[0.201]	[0.202]
Parental background								
Basic education level				0.121[b]				−0.119
				[0.053]				[0.198]
1st and 2nd educational level cycles				0.121[b]				−0.337
				[0.058]				[0.210]
3rd educational level cycle				−0.018				−0.223
				[0.100]				[0.347]
Parent professional career in firms				0.171[a]				0.246
				[0.066]				[0.251]
2006 year	−0.056[c]				−0.184[c]			
	[0.031]				[0.106]			
Constant	0.175[c]	0.237	−0.352	−0.449	−1.712	−1.230	−10.750	−11.129[a]
	[0.346]	[0.396]	[0.736]	[0.746]	[1.262]	[1.339]	[3.974]	[3.959]
(1/df) Pearson	1.009	1.014	1.000	1.000	1.024	0.986	0.979	0.985
AIC	0.515	0.511	0.529	0.528	1.051	1.031	1.159	1.172
BIC	−92,392.86	−62,661.44	−23,180.72	−23,162.19	−4597	−3022.03	−992.18	−974.76
Number of observations	10,575	7471	3104	3104	830	584	246	246

Robust standard errors in square brackets.
[a] Significant at 1%.
[b] Significant at 5%.
[c] Significant at 10%.

In the second part of the analysis, estimations were made to determine which factors conditioned PhD careers in the manufacturing sector. Examining Model 5, the results revealed that knowledge area remained an important factor, but some differences were detected with respect to Model 1. For instance, physics and electrical engineering did not have a significant influence in explaining careers

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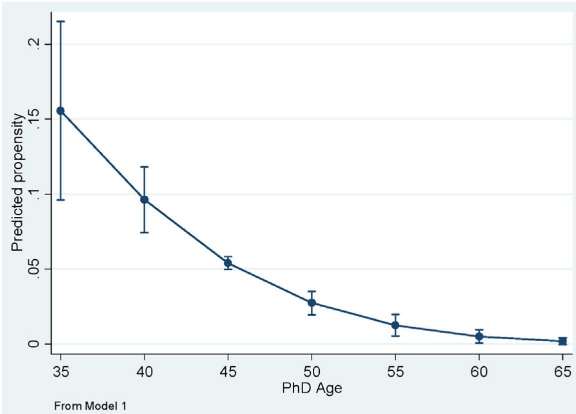

Fig. 1. Propensity to pursue careers in the private sector according to PhD Age.

in the private sector, but they were determinants of explaining careers in the manufacturing sector. Differences were also detected with regard to the type of research carried out and the length of PhD training. Having conducted only technological development significantly reduced the propensity to pursue a career in manufacturing, and the PhD duration did not show a significant influence. For careers in the manufacturing sector, the specific knowledge area was more important compared with how the PhD training was performed. Some differences were also uncovered with regard to PhD funding. Individuals who did not have a competitive grant (from a national or an international government) and who obtained funding from loans or family sources had a lower propensity to pursue a career in the manufacturing sector. Unlike the results obtained for the private sector, it was observed that grants from public administrations did not have a significant influence in pursuing a career in the manufacturing sector. As a result, the Spanish public policy may not be encouraging scientific knowledge transfers to industry. Focusing on the information related to the particular position, the results revealed a change in tendency with regard to the variables regarding the minimum study level required for the current job. Unlike the results based on the private sector (Model 1), PhD holders in manufacturing firms found jobs requiring university studies or at least that recognized such studies.

The analysis also revealed an interesting result with regard to age. In general, studies have not reached a definitive conclusion with regard to this variable (as was explained earlier), but this study revealed that a different mobility pattern exists between the private sector and the manufacturing sector. While in the private sector (Model 1), mature age reduced the propensity to pursue a career in firms, in the manufacturing sector (in general), age had no significant influence. Nevertheless, considering the estimations by year, in 2009 (Model 7), manufacturing firms were more interested in recruiting PhD holders with extensive field research experience.

Finally, as in the private sector case, this study revealed differences between years in the manufacturing sector sample. Physics had a significant influence in 2006 but not in 2009. Similar results were detected for electrical engineering and mechanical engineering, which only had a significant influence in 2009, and the influence of mechanical engineering was negative. These results reveal, as explained previously, that although the knowledge remained important, the industry's demand for certain knowledge areas was not always the same through time. Other differences were detected for sources of PhD funding and for unemployment time, neither of which were significant in 2009, which demonstrates tendency changes in the labor market. Despite differences remaining with respect to the variables regarding the minimum study level required for the current job, in general, PhDs in the manufacturing sector went to firms that required university studies. Finally, the study only found a negative and significant influence of gender in 2006 (Model 6). Females showed a lower propensity to pursue careers in manufacturing firms. This result could explain the low female participation in the knowledge areas that are more in demand for these firms.

5.1. Robustness checks

Models 4 and 8 in Table 3 report a supplementary analysis carried out to check for robustness. This analysis was performed only for the 2009 sample because in that year, the HRST survey introduced new variables that recorded information on the PhDs' socio-economic background, such as parental education level and parental professional activity. Although the literature has established that parents' educational level can be an important predictor of an individual's motivation to apply to a PhD program (see Duberley and Cohen, 2010; Lin, 2011; Pan and Lee, 2012), insufficient evidence exists to establish whether this relationship extends up to the point of selecting a career in the private sector. Enders (2002) analyzed social background with regard to the probability of PhD employment inside and outside of the academic environment (that is to say, in governmental organizations, private industry and nonprofit organizations) and found no indications of a class bias in connection with the great majority of disciplines considered, except for the case of business/economics, in which the author uncovered a significantly low bias toward a high parental academic background with regard to employment outside of the higher education and research sectors. In relation to parental professional activity, the literature linking scientists with the entrepreneurial world has established that those scientists with family members working for firms could be more prone to pursue commercial activities or to seek jobs outside of the academic environment (Haeussler and Colyvas, 2011). A family environment enables one to construct a social network that can grant scientists access to critical information and enable them to contact private sector networks (Dyer and Handler, 1994).

Based on the foregoing, this study included four dummy variables for socio-economic background to check for robustness. The first three variables recorded whether the PhDs' parents had completed only basic studies, undergraduate studies or graduate studies. Because the survey did not record information about the parents' entrepreneurship orientation, the fourth dummy variable reported whether parental professional activity was developed in firms. Estimations were made for the private sector careers (Model 4) and the manufacturing sector careers (Model 8). The highest Variance Inflation Factor (VIF) was 1.33 (with a mean of 1.09) after including the new variables. In Model 4, the results remained robust in the presence of the socio-economic background variables, and no important changes in the coefficients or the p-values were detected. Parents' educational background had an effect on the decision to pursue a career in the private sector; as a result, it was corroborated that the family influence can extend up to pursuing a career or job. In the same manner, we confirmed that the parents' occupational sector has a significant impact. PhD holders with parents working in firms had a higher propensity to end up working in the private sector. Evidence has therefore been found in this study that a family environment that maintains links with enterprises positively reinforces the desire to engage in a career in the private sector. This study has also found a different mobility pattern when analyzing careers in the manufacturing sector (Model 8). Despite the introduction of the socio-economic background variables, the results remained robust, although none

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had a significant influence in the case of the manufacturing sector. Only one difference was detected with respect to the variable loans or family funding, which showed a significant and negative influence ($p < 0.10$) in the presence of the socio-economic background indicators.

6. Conclusions

This study has analyzed the factors conditioning PhD careers in the private sector in general and in the manufacturing sector in particular. The statistical analysis was carried out on a sample of Spanish PhD holders who are currently facing important changes in their labor market. Traditionally, Spanish PhD holders have been employed in the public sector, but the economic crisis has now forced them into the private sector. The excessive accumulation of PhDs in the Spanish public sector (80% of PhDs surveyed were employed in this sector) contrasts with the low PhD employment rate in the private sector. This has become a serious problem for Spanish firm competitiveness because scientific knowledge is not being transferred intensively to industry through science and technology human resources. A descriptive analysis of PhD employment in the manufacturing sector revealed that, although Spanish PhDs maintain a substantial role in the chemistry industry (which employed 61% of all of the surveyed PhDs), they were not generally important across a broad segment of the manufacturing sector. In addition, PhDs in computer science and mathematics, two areas that are considered especially relevant for the industry's future, represented less than 1% of the PhDs working in manufacturing firms. In this context, it remains important to understand the complex scientist mobility process to firms.

This study has used data derived from the Spanish Survey on Human Resources in Science and Technology. The first part of the analysis, which was directed toward analyzing the factors that determine a PhD's choice of career in the private sector, indicated that mainly PhD holders in the sciences had a higher propensity to be employed in this sector. In the same vein, PhDs who carried out technological development activities, had received national or international grants, had been unemployed for several months or had received family funding or loans all increased the propensity to become engaged in the private sector. The study has also revealed that this propensity was reduced with increasing PhD age and with longer PhD training periods. No remarkable differences were detected between the survey years of 2006 and 2009 except for the research type carried out, the financing type and age. Altogether, these results confirm those that have previously been obtained in the literature that analyzes PhD careers in the private sector (Mangematin, 2000; Zucker et al., 2002b; Dany and Mangematin, 2004; Recotillet, 2007; Roach and Sauermann, 2010; Fritsch and Krabel, 2012).

In the second part of the analysis, estimations were conducted to determine whether different PhD careers existed within the private sector. Concretely, the study used the same predictors to analyze careers in the manufacturing sector. The results revealed a different career pattern compared with that obtained from the general private sector analysis. For example, while the physics and engineering electrical areas did not display a significant influence on the pursuit of a career in the private sector, they nevertheless showed a significant influence on the pursuit of a career in manufacturing firms. Other differences were detected regarding the research type carried out and the length of PhD training. Having completed only technological development during PhD training increased the propensity to pursue a career in the private sector but reduced the probability of obtaining a job in the manufacturing sector. PhD financing also constituted a differentiating factor: Individuals who financed their PhD with loans or family resources had a higher propensity to pursue a career in the private sector, yet this type of financing reduced the propensity to pursue a career in the manufacturing sector. Unlike in other studies, this study included the minimum study level required for the current job. In the private sector, the results revealed that PhDs were employed in positions that did not require university degrees, which was not the case in the manufacturing sector. Finally, an interesting difference was detected in connection with age. Whereas the private sector rewarded youth, the tendency in the manufacturing sector was to prefer older PhDs. The detected differences revealed that the private sector cannot be considered a homogeneous work place for PhD holders anymore. Controlling for the firm activity sector, the influence of certain predictors changed, thus leading to different PhD careers within the private sector. Another important contribution of this study concerns the complementary robustness check analysis that was undertaken. This study has included indicators of the PhDs' socio-economic background. The results revealed a significant influence of the parents' educational and professional background on PhDs' decision to pursue a career in the private sector but not in the manufacturing sector. As a result, further research is needed to continue to advance this topic.

The PhD career differences detected for the private sector as well as the differences detected between years confirm that non-academic factors could in principle explain the high degree of PhD career variation. Traditionally, the literature has focused on academic factors, but more contextual factors should also be analyzed. Between the two surveyed years, this study detected some predictor variable changes, including with respect to knowledge areas and funding. Future research should also establish whether such changes are produced by new discoveries that are useful to firms, PhD supply changes or changes in the available public funding.

This study is not without limitations. The survey lacks important predictors for careers in the private sector, such as previous cooperation with firms or private funding for PhD studies. Although the survey also records information with regard to the number of publications and patents, this information has not been used, as the survey did not establish whether they had been obtained before or after the PhD's incorporation into firms. Consequently, several important aspects have not been analyzed, and the results should be interpreted while noting the lack of this information.

All things considered, this study has important implications for PhDs and policy makers. PhDs should consider active participation in research activities involving firms during the early stages of their PhD training while reducing a possibly excessive academic orientation. Universities will have to reorient their programs toward strengthening the research lines oriented to transforming scientific knowledge into goods and services, promoting university-private sector associations and even encouraging early mobility to firms during the PhD training period. Finally, governments should not halt their efforts to encourage the mobility of scientists to firms so they can reinforce the transfer of scientific knowledge into industry.

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Appendix 1. Correlation matrix and descriptive statistics

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. PhD in firms (DV)	1.00																				
2. Biology	0.04	1.00																			
3. Chemistry	0.11	−0.10	1.00																		
4. Physics	−0.01	−0.08	−0.07	1.00																	
5. Material science	0.02	−0.02	−0.02	−0.02	1.00																
6. Medical science	0.04	−0.15	−0.14	−0.11	−0.03	1.00															
7. Chemical engineering	0.01	−0.03	−0.03	−0.02	−0.01	−0.05	1.00														
8. Electrical engineering	−0.02	−0.06	−0.05	−0.04	−0.01	−0.08	−0.02	1.00													
9. Mechanical engineering	0.00	−0.04	−0.03	−0.03	−0.01	−0.05	−0.01	−0.02	1.00												
10. Biotechnology	0.06	−0.04	−0.03	−0.03	−0.01	−0.06	−0.01	−0.02	−0.01	1.00											
11. Technological development	0.02	−0.03	0.01	−0.01	0.00	0.05	0.00	−0.01	0.02	−0.01	1.00										
12. National grant	0.07	0.16	0.16	0.07	−0.01	−0.14	0.03	−0.03	−0.03	0.04	−0.02	1.00									
13. Foreign grant	0.02	0.01	0.04	0.03	−0.01	−0.02	0.01	0.00	−0.01	0.01	0.01	−0.07	1.00								
14. Loans or family funding	0.01	−0.05	−0.06	−0.07	−0.01	0.16	−0.02	−0.05	−0.02	−0.03	0.02	−0.28	−0.03	1.00							
15. PhD training length	−0.07	−0.08	−0.09	−0.05	−0.01	0.02	−0.03	−0.03	−0.02	−0.03	0.01	−0.19	−0.01	0.06	1.00						
16. Diploma	0.02	0.01	0.01	−0.02	−0.01	0.06	0.01	−0.01	−0.01	−0.01	−0.01	−0.02	0.01	0.01	0.00	1.00					
17. Pre-university studies	0.07	0.05	0.00	−0.01	−0.01	−0.03	0.00	−0.01	−0.01	0.05	−0.01	0.00	−0.01	0.01	0.01	−0.01	1.00				
18. Unemployment time	0.10	0.10	0.08	−0.01	−0.01	−0.04	0.01	−0.05	−0.03	0.04	−0.01	0.16	0.00	0.01	−0.08	0.01	0.06	1.00			
19. Age	−0.08	−0.10	−0.13	−0.07	0.01	0.14	−0.04	−0.07	−0.03	−0.04	0.04	−0.29	−0.02	0.14	0.29	−0.02	−0.01	−0.13	1.00		
20. Female	0.03	0.06	0.04	−0.09	−0.02	0.03	−0.01	−0.11	−0.06	0.02	0.01	0.08	0.01	−0.01	0.00	0.02	0.01	0.06	−0.12	1.00	
21. Married	−0.01	−0.05	−0.04	−0.02	0.01	0.09	0.00	0.01	0.01	0.00	0.01	−0.09	−0.01	0.04	0.04	0.01	0.00	−0.06	0.20	−0.09	1.00
Mean	0.09	0.09	0.08	0.05	0.00	0.21	0.01	0.03	0.01	0.01	0.02	0.32	0.01	0.16	5.74	0.01	0.01	1.27	41.32	0.45	0.65
S.D.	0.29	0.29	0.27	0.21	0.07	0.41	0.11	0.16	0.10	0.12	0.15	0.46	0.08	0.37	3.09	0.09	0.11	2.48	7.89	0.50	0.48

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Liliana Herrera is an associate professor at University of León. Currently her research is focused on dynamic processes of innovation and knowledge creation in firms, evaluation of innovation policies, the study of regional innovation systems and mobility of researchers. She has participated in several research projects financed by a broad range of institutions in Spain.

Mariano Nieto is Professor of Strategic Management and Innovation Management in the Faculty of Economics and Busines Administration at the University of León (Spain). He holds a PhD in Business and Economics from University Complutense of Madrid since 1992 and his research interests include innovation management and corporate social responsibility. He has published in international journals such as Technovation, Research Policy, Journal of Business Research, Technological Forecasting & Social Change, or Industrial Management and Data Systems.

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