Mobility of Public Researchers, Scientific Knowledge Transfer, and the Firm´s Innovation Process

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ABSTRACT

The present study provides evidence on the mobility effects of researchers from the public R&D system with regard to firm´s innovation process. This issue is particularly novel and important as these researchers contribute to the production and transfer of knowledge previously developed and accumulated in the public R&D system. The findings confirm that scientific knowledge which public researchers provide has a positive influence on both inputs and outputs of the firms' innovation process. The fact that firms have access to additional knowledge which is complementary to that they already hold represents a spur for exploiting and applying this new knowledge. The firms in this study continually increased their in-house R&D investments. As a result of these investments firms create new knowledge of a unique and valuable type. The study draws two important conclusions geared to providing a greater efficiency in human resource management and to improve the design of technology policies.

Keywords: innovation management, scientific knowledge transfer, knowledge management, public researchers mobility, R&D.

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INTRODUCTION

The intensification of innovation activities leads to technological changes which, in turn, stimulate economic growth and increase welfare levels in societies where this occurs (Landes, 1998). For this reason, governments in every country design active technology policies and set in motion a large variety of programs to promote innovation. These programs are geared to producing more efficient resource allocation for innovation activities and correcting the market failures which occur through the production and diffusion of technological knowledge (Arrow, 1962). In this context, many countries implement mobility programs allowing companies to access new knowledge by contracting foreign researchers from public research centers and universities. These programs have a dual aim of stimulating firms' innovation effort (by increasing inputs of the innovation process) and enhancing the efficiency of innovation activities (by increasing the outputs of the innovation process).

Firms, that are the main agents in the innovation process, see how performing innovation activities produces a never-ending source of competitive advantages (Barney, Wright, and Ketchen, 2001; Subramaniam and Youndt, 2005). The most competitive firms develop proactive strategies toward innovation and exploit their innovatory potential by deploying the whole gamut of their technological resources and capabilities. In this manner, they exploit technological knowledge they have access to for the periodical introduction of new products onto the market and a continuous improvement of production processes (Zack, 1999).

The innovation process in firms is a process of accumulating and creating new knowledge (Nonaka and Takeutchi, 1995; Zahra and George, 2002). The performance of this process depends in a critical fashion upon the firm's capacity to manage the knowledge and human resource practices they use (Chen and Huang, 2009). Different authors show that firms' innovation capacity is closely related to their ability to take advantage of the knowledge they possess (Subramanaiam and Youndt, 2005) and combine them with other knowledge stemming from outside (Yli-Renko, Autio, and Sapienza, 2001). Innovation is built on collective knowledge sharing activities and frequent interaction between different individuals and groups (Gold, Malhorta, and Segars, 2001).

In this framework, the mobility of scientific staff from the public R&D system is an option enabling firms to access new knowledge and improve the exploitation of the knowledge they possess (Almeida, Dokko, and Rosenkopf, 2003). Evaluating this type of mobility is important because the researchers make a contribution to the transfer of previously developed knowledge accumulated in the public R&D system (Bozeman, Dietz, and Gaughan, 2001; Cassia and Colombelli, 2008; Correia and Petiz, 2007; Lundvall, 1992; Pavitt, 1991, 2000; Moen, 2005; Salter and Martin, 2001). The hypothesis that the scientific staff mobility impinges positively on inputs (innovation effort) and outputs (new products) of the innovation process are sustained by evidence and arguments from academic literature. The scientific knowledge which public researchers provide offers new opportunities to promote firms' innovation effort (Ahuja, Lampert, and Tandon, 2008) and, in combination with knowledge which the firm already has, creates new opportunities for new product development (Cohen, Nelson, and Walsh, 2002; Yli-Renko, et al., 2001).

The literature stresses that the mobility of personnel coming from the public R&D system allows firms to gain access easier to potentially highly valuable knowledge. Although there is a tendency to underrate the economic value of scientific knowledge, some authors show that the findings of research carried out by scientific researchers in the public sector are of greater commercial impact than those from the private sector (Czarnitski, Hussinger, and Schneider, 2008). Technology historians all point out that scientific knowledge plays a determining part in technological progress (Landes, 1998). Czarnitzki et al. (2008) show that the volume of scientific knowledge that public institutions produce is higher than the production of business R&D departments, in addition, Agrawal and Henderson (2002) add that the range of applications and social value of public research are higher than that of the research that the private sector carries out. In this sense, the stock of knowledge that scientific researchers produce in universities and public research centers has a positive repercussion on economic growth (Adams, 1990; Griliches, 1984) and productivity in industry (Adams, 1990). Moreover, the knowledge that those researchers produce has a greater likelihood of leading to radical innovations (Czarnitzki et al., 2008; Zucker, Darby, and Brewer, 1998).

Some authors dispute the above arguments and query the effectiveness of the mobility in encouraging innovation effort and improving firms' innovations results. The literature points out that integrating the knowledge that scientific researchers contribute in the firms' stock of accumulated knowledge is not automatic and may impinge negatively upon the innovation process (Kessler, Bierly, and Gopalakrishnan, 2000). Academic literature identifies several factors that hinder incorporation of external knowledge and its transfer within the organization. Knowledge assimilation depends decisively upon the firm's previously developed capacity of absorption (Cohen and Levinthal, 1990) and how "stickiness" in communication between scientists is an obstacle (Szulanski, 2000). What is more, within the organization resistance may arise which could hinder the integration of scientific researchers and the acceptance of the knowledge they provide. This may be the result of the well-known NIH (Not Invented Here) syndrome (Katz and Allen, 1982), which is manifested in a preference for knowledge developed in house and the rejection of knowledge from outside. Various works also identify the difficulties posed by the transfer and assimilation of scientific knowledge characterized by its complexity and high tacit dimension (Bonache and Zarraga, 2008; Kaiser, 2002)

Another factor which might diminish the positive effect of the mobility on business innovation is concerned with the different nature of both forms of knowledge. Some authors empirically contrast the relationship between knowledge accumulated by the firm (private nature) and scientific knowledge that researchers from the national innovation system provide (public nature) (Trajtenberg, Henderson, and Jaffe, 1997). In general, public center researchers produce knowledge under an open regime which facilitates the interchange and diffusion of findings. The structure of incentives which these researchers-respond to (e.g. peer evaluation, academic recognition, etc,) stimulates the rapid spread of findings and reinforces the public nature of scientific knowledge. By contrast, carrying out R&D activities in firms is in response to economic incentives and the benefits they can generate depend, to a great extent, upon the knowledge they produce not being accessible to third parties (Dasgupta and David, 1994).

Advantages springing from the mobility of scientific researchers can lead to questions from a theoretical plane as being inconsistent with the basic hypotheses of the Resource Based View (RBV) and the transaction cost theory. In this sense, the RBV predicts that firms will obtain and maintain a competitive advantage over time only if they have valuable resources which are scarce, irreplaceable and difficult to copy

(Barney, 2001). Doubts arise concerning the possibility of the knowledge which public researchers provide passes the filter of those four conditions and contributes significantly to the firm’s competitive position. There are reasons to believe that this type of knowledge is difficult to protect due to the nature of the incentives which led scientific researchers to make the findings of their research public. This problem could have a solution through taking on the cost of establishing suitable property rights.

Access to scientific knowledge through mobility brings about transaction costs greater than those of other forms of access. When researchers coming from the public R&D system join firms there are three types of cost involved stemming from a difficulty to: a) define and delimit the content of knowledge and formalize its transfer (costs of a cognitive nature due to the tacit component of knowledge), b) define property rights over knowledge (due to its intangible nature common to all the assets of knowledge and the propensity of public researchers to publish), and c) reduce the uncertainty surrounding the transaction process (Arora and Gambardella, 2008).

These doubts concerning the effectiveness of the mobility of scientific researchers suggest the need to study the effects they have on a firm’s innovation activity. Literature, fairly recently, analyzes the relationship between mobility of public researchers and scientific productivity (Crespi, Geuna, and Nesta, 2007; Hoisl, 2007; Zucker, Darby, and Torero, 2002). Even though the literature assumes that mobility produces positive effects on firms’ innovation processes, there is a need to extend knowledge on this relationship and compare it empirically. No work analyzes the impact of these practices on the innovation process in a firm by isolating the effects upon inputs and outputs. This analysis is necessary to elucidate if the knowledge that public researchers provide on joining a company has the greatest effect on stimulating the firm's innovation effort or on increasing the firm's innovation productivity. This work aims to provide an answer to these questions.

This article has the following structure: section two presents the background and the hypotheses of the study, section three describes the method, section four presents data and variables, section five discusses the results of the empirical analysis and section six presents the conclusions.

BACKGROUND AND HYPOTHESIS

The success of the innovation process depends, largely, on firm's need for knowledge, as well as the implementation of knowledge management practices which allow to explore and exploit the knowledge (Levinthal and March, 1993; March, 1991). In fact, knowledge is the most critical competitive asset that a firm owns and resides in its human capital (Hitt, Bierman, Shimizu, and Kochhar, 2001). People are the repositories of knowledge, creativity and capacity to transform information, skills and ideas into new results. Academic literature coincides in pointing out the importance of the human resources system in a firm's capacity to create new knowledge (Kamoche and Mueller, 1998; Lepak and Snell, 1999), and, in turn, distinctive competences (core capabilities) which can serve as a basis for their success (López-Cabrales, Valle, and Herrero, 2006). For this reason, firms develop mechanisms geared to obtaining new knowledge: a) from in-house sources by means of training human capital to increase its value and specific nature (Lepak and Snell, 1999), b) through outside sources by acquiring human capital with the most suitable characteristics (Muñoz-Doyague, González-Álvarez, and Nieto, 2008), or c) combining both (De Saá Pérez and Díaz Díaz, 2007).

In this context, the management of human resources has a central role in a firm oriented towards innovation (Burgoyne, Pedler, and Boydell, 1994). There is an abundance of literature analyzing the relationship between human resources practice and innovation (Chen and Huang, 2009; Laursen, 2002; Laursen and Foss, 2003; Leede and Looise, 2005; Shipton, West, Dawson, Birdi, and Patterson, 2006). However, there is scarcely any analysis of the complementary effect that different knowledge acquisition strategies bear (De Saá Pérez and Díaz Díaz, 2007; Helfat, 1997; Zack, 1999). For example, firms can consider obtaining knowledge through hiring researchers who arrive trained (Almeida et al., 2003). This process guarantees that the human capital contracted not only has the knowledge and skills, but is also as a work force sufficiently scarce to successfully deal with the process of innovation (Lepak and Snell, 1999).

This study evaluates the role researchers coming from the public R&D system performance in the process of transferring their knowledge to the firm which hired them, whilst assessing the contribution of this scientific knowledge to the development of the firm's innovation strategy.

The study of the movement of public researchers to firms is very recent and centers on the analysis of two questions: what factors impinge on the mobility of scientific researchers and what is the relationship between mobility and productivity. In the former case, studies reach the conclusion that different types of factors influence the decision that a scientific researcher adopts when moving to a firm. Those factors are: factors regarding the individual's characteristics, among them the previous contact with the private sector (Crespi et al, 2007; Gaughan and Robin, 2004; Mangematin, 2000; Zucker et al. 2002), factors concerning the institutional and social context (Breschi and Lissoni, 2001), factors owing to the public R&D system (Bozeman and Gaughan, 2007) and factors in line with the characteristics of the firm hiring the researcher (Hoisl, 2007; Mangematin, 2000). This literature is not definitive as to which is the dominant factor in the decision-making process.

The analysis of the relationship between mobility and productivity is complex, since the literature shows that mobility takes place, in many cases, on the basis of the researcher’s scientific productivity. According to Zucker et al. (2002), scientific researchers are quicker to make the decision to move to a firm if they have higher human intellectual capital and if that capital is important for obtaining innovatory results with commercial value. Thus, the study of these relationships presents a problem of endogeneity which one should bear in mind in order to obtain coherent estimates of the effect at this level (Hoisl, 2007; Trajtenberg, 2005; Tratjenberg, Shiff, and Melamed, 2006).

Studies approaching the subject of mobility at a firm level are even rarer and centre on the study of the development of certain industrial sectors, principally in the biotechnology sector (Zucker et al., 1998; Zucker et al., 2002). Even though the literature adopts the individual as a unit of analysis, little is known about the characteristics of the firms that profit from the mobility. Recent studies show that a variety of firm characteristics could have an influence on the mobility effect of public researchers. The study undertaken by Hoisl (2007) finds that firm size, together with the concentration of innovation activity and geographical location, all produce a significant influence. The study by Crespi et al. (2007) suggests that specific conditions of the sector activity affect the mobility, while the studies of Cruz-Castro and Sanz-Menéndez (2005) conclude that if the mobility is toward a firm that has a certain amount of absorption capacity, then firms obtain innovation outputs more easily.

This literature assumes that mobility may give rise to positive effects on firms' innovation activity; however this assumption must be empirically analyzed. Fairly recent studies merely conclude that hiring scientific researchers may have positive effects on R&D management, on the training of human resources and, finally, on the coordination among the different functional areas (Cruz-Castro and Sanz-Menéndez, 2005; Zellner, 2003). This literature does not analyze the effects of the mobility on the firms' innovation processes; even though the same literature points out that scientific progress may act as a direct or indirect stimulus on the private R&D effort and on the obtaining of innovatory results. Researchers coming from the public R&D system contribute to this process in different ways.

From the innovation effort standpoint, the literature recognizes that hiring public researchers increases the firms' scientific knowledge stock and leads them to the most recent technological advances enabling them to create a sustainable competitive advantage. The fact of having access to knowledge complementary to that already in the hands of the firm, represents in itself a stimulus to exploiting and applying this new knowledge (Dosi, 1982). Moreover, in order to take advantage of this knowledge, the firm has to create a certain absorption capacity so that this knowledge can be understood, modified and assimilated with the aim of developing innovatory products and processes (Cohen and Levinthal, 1990). Ahuja et al. (2008) explain that this absorption capacity is sustainable if the firm is continually investing in R&D. The role of scientific researchers in this process is important, not just because they increase the firm's stock of knowledge, but also because they orientate discussion on R&D investment. Therefore, this study formulates the following hypothesis. Hypothesis 1: The mobility of researchers from the public R&D system to firms influences the innovation effort (input).

Also, the knowledge that public researchers provide makes it easier for firms to obtain innovatory results. The literature assumes that, owing to the knowledge of the highly qualified personnel, the possibility exist to overcome various difficulties that arise during the development of a new technology or in the absorption of an already created one. This idea arises from empirical studies carried out on R&D personnel that showed that attributes such as intrinsic motivation (Amabile, 1988; Muñoz-Doyague et al., 2008; Tierney, Farmer, and Graen, 1999) and possessing a cognitive style (Muñoz-Doyague et al., 2008; Payne, Lane, and Jabri, 1990; Scott and Bruce, 1994; Tierney et al., 1999), or expertise (Tierney et al., 1999) are positively related to achieving innovative results. Recent research shows that the commercial value of the results of the experimentation carried out by public investigators is higher than that carried out by researchers in the private sector (Czarnitzki et al., 2008), also that the knowledge produced by public research is more likely to produce breakthrough inventions (Freeman, 1992; Kaufman and Tödtling, 2001). Consequently, in this study we formulate the following hypothesis. Hypothesis 2: The mobility of researchers from the public R&D system to firms influences the innovation performance (output).

This analysis makes a distinction between inputs and outputs of the innovation process. In most empirical studies carried out in the areas of innovation economics and management, researchers use both outputs and inputs as innovation measures (Cohen and Levin, 1989). The R&D expenditures measure the inputs of the innovation process, while patents are the outputs. Several studies analyzing the relationship between input and output present contradictory results. On the one hand, studies detect a strong positive correlation between these two indicators and on the other, there are studies which indicate the existence of diminishing marginal returns and that the elasticities of this knowledge production function vary and depend on firm size (Griliches, 1990), with larger firms showing lower R&D productivity (Arbussá, Bikfalvi, and Valls, 2004).

Auja et al. (2008) review the studies which show explicitly the difference between these two indicators. The problem of innovation inputs is a question of incentives and backup resources for research (Galbraith, 1952; Tirole, 1988), whereas the problem of outputs is related to research productivity and the factors determining the level of results (Kamien and Schwartz, 1982). Public researchers increase the stock of knowledge in a firm (input), and this is a critical component of the innovation process. In turn, this knowledge stock improves the firm's position for developing new products and processes (output).

This study includes an analysis of the way firms distribute R&D expenditure between internal and external expenditure to examine the influence that public researchers have on the strategy for obtaining knowledge in the early stages of the innovation process. Knowing how firms acquire and assimilate knowledge turns out to be the key factor. Evaluation of the mobility effects on the total R&D expenditure could perhaps not record the mobility`s influences on either the decision to generate more knowledge that increases the competitive advantage or on the decision taking to acquire the knowledge from outside sources.

METHOD

This study applies a non-parametric pairing method, known as propensity score matching (PSM). This method estimates the effect of a binary treatment (M) on variables denominated potential outcomes (Y). The method estimates the effect of employing personnel coming from the public R&D system on the firms' innovation activity Y_i. The method specifically compares the results achieved by those firms that hire public researchers Y_{1i} (factual state) with the results that they would have obtained if they did not hire public researchers Y_{0i} (counterfactual state).

Since a firm *i* cannot be simultaneously under observation when it hires or does not hire public researchers, the counterfactual state turns out to be the fundamental evaluation problem. The PSM estimates the counterfactual state from the information available on the firms that do not hire, which form part of a control group. The construction of this group is not easy, since the employment of researchers coming from the public R&D system is not a random process and the firms that employ differ from those that do not employ. This produces a problem which econometric studies call sample selection bias. The PSM reduces this bias by means of a matching method, which compares the firms that hired with those firms that did not hire and which are similar in terms of their observable characteristics X_i. Due to the fact that the matching of firms of many characteristics *n* in an n-dimensional vector is generally unfeasible, the method reduces the characteristics of each firm to a scalar variable or Propensity Score (PS) in order to make the matching more feasible. The PS is the conditional probability of employing researchers from the public R&D system given a group of pre-treatment characteristics X_i. In this way, the method compares the firms that hired with those firms that did not hire but which have the same likelihood of hiring public researchers. The PS could be estimated using a probit or logit model. This study uses a probit model, as the method is one of the most frequent to appear in the literature. This investigation, not only estimates the PS for each firm, but also analyzes the conditional variables X_i which have an influence on the likelihood to hire public personnel.

A matching method is necessary to find two firms with the same PS value. Becker and Ichino (2002) compare several methods (e.g., nearest neighbor matching, radius matching, kernel matching and stratification matching). Though all the methods arrive at the same result, in accordance with Heckman, Ichimura, and Todd (1997), the choice between one method and another is only important in the case of small samples. This study uses the nearest neighbor matching method, which is one of the most common found in the literature. This method chooses for each unit treated a control group unit which has the closest propensity score.

Once the control group is available, estimating the causal effect requires compliance with a series of assumptions to ensure that the employment distribution is random and that the counterfactual state is estimated on the basis of the control group. Meeting these assumptions requires the researcher to know the variables which influence on the likelihood of hiring researchers from the public R&D system. For these assumptions to be plausible this study chooses a broad set of variables which, according to the literature, influence on the likelihood of employing. The PSM also requires observations with the same PS to have the same distribution of observable characteristics, regardless of the status of the treatment, as a balancing property. The algorithm of Becker and Ichino (2002) is undertaken to test the balancing property and to estimate the causal effect. This algorithm tests whether the means of each characteristic differ between the one treated and the control units.

Finally, if Y_i represents a firm's innovation activity, M takes the value of 1 when the firm *i* hires public researchers and zero in the opposite case, and $P(X_i)$ represents the propensity score, then it is possible to estimate the effect of the mobility of public researchers τ as the difference between the innovation activity of firms that hired and the innovation activity of firms that did not hire, thus:

$$\tau = E\{E\{Y_{1i} \mid \mathrm{M}_i = 1, \mathrm{p}(\mathrm{X}_i)\} - E\{Y_{0i} \mid \mathrm{M}_i = 0, \mathrm{p}(\mathrm{X}_i)\} \mid \mathrm{M}_i = 1\} \quad (1)$$

From the work by Rosenbaum and Rubin (1983), the PSM has a broad use in the evaluation of policy interventions and recently in the evaluation of innovation policy at a micro level (Almus and Czarnitzki, 2003; Herrera and Heijs, 2007). Dehejia and Wahba (2002) thoroughly review this method. The study by Arvanitis and Keilbach (2002) undertakes a comparative analysis between the PSM and other methods used to evaluate treatment effects. A review of the sample selection bias problem and a comparative study of the different methods for overcoming it can be found in Heckman, Ichimura, Smith, and Todd (1998).

DATA AND VARIABLES

Data

The data analyzed in this study arises from the Business Strategy Survey (Encuesta sobre Estrategias Empresariales - ESEE), sampled by the SEPI Foundation. The survey annually records information on the strategic behavior of Spanish firms with more than 10 employees. Data arise from two subpopulations of Spanish firms. One is formed by firms with more than 200 employees and the other by firms of 10 to 200 employees. The response rate was 60% and 4% respectively. Firms belong to the divisions 15 to 37 of the sectoral classification CNAE-93 corresponding to the manufacturing sector. Fariñas and Jaumandreu (1999) describe in detail the data and variables. The authors also undertake an analysis concerning the descriptive power and prediction capacity of the survey.

Since 1998 the survey collects detailed information on the firms' innovation activity, including information on the degree of organization of the innovation activity, technological cooperation and R&D funding difficulties. The survey also gathers information about the mobility of personnel coming from public R&D system to firms.

This analysis uses data of the period covering the years 1999 to 2001. This study estimates the effect of the mobility of public researchers on the innovative activity of firms in the same year the mobility took place (2000) and also a year later (2001). The treatment variable, that is, whether hired personnel coming from the public R&D system or not in the year 2000, acquires its determination from lagged explanatory variables, in other words, pre-treatment values in 1999, thereby reducing endogeneity problems and thus also improving the quality of matching.

In order to identify the firms that hire (treatment group), a dichotomous variable took the value of 1 if the firm hired personnel belonging to the public R&D system in the year 2000, and 0 if not. Out of all the firms who replied to the survey in each of the three consecutive years, a total of 495 firms were considered to construct the sample analyzed. In the sample only 35 firms benefited from the mobility. Although the survey contains a representative sample of firms belonging to the Spanish industrial sector, the low number firms in the control group reflects the limited mobility of public researchers in Spain. Other European countries exhibit the same tendencies. For instance, taking into consideration the Spanish program that encouraged the employment of Doctors by firms (at the moment called Torres-Quevedo), the mean number of firms that requested the aid in the period of analysis (1999-2001) did not exceed 85 (see Sanz-Menéndez, Cruz-Castro, and Aja, 2004). This study made use of a total of 70 firms to analyze the effect of mobility (35 firms which hired public researchers, plus 35 firms in the control group).

Variables

The estimation of the propensity score (in other words, the conditional probability that firms have of hiring personnel coming from the public R&D system) is a preliminary step necessary to estimate the causal effect. This study selects variables (X_i) which explain this conditional probability among those that according to the literature have an influence on the innovative behavior of firms (Cohen, 1995) and also among those that could have an influence on the mobility of scientific researchers at the firm level (Crespi et al., 2007; Cruz-Castro and Sanz-Menéndez, 2005; Hoisl, 2007; Zellner, 2003). A review of these studies identifies three groups of variables, namely, variables associating with the firm's characteristics, its innovative behavior, and the firm's market. Table 1 gives a description of these variables.

This study considers size and age of firms as indicators reflecting management capacity and ability to obtain resources, together with experience. Following the typology introduced by the OECD, this paper classifies industries into High-tech, Medium-tech and Low-tech sectors in order to control for sector differences as to technology level accumulation. This analysis also includes an indicator of the firm's location in order to verify whether the proximity to a large concentration of infrastructures supporting innovation influenced on the propensity to benefit from this mobility. This paper differentiates between firms located in central regions of the Spanish innovation system (Catalonia, Basque Country and Madrid) and firms located in peripheral regions following the work of Herrera and Nieto (2008). A variable with information about the firm's ownership figures to confirm the influence of the participation of foreign capital.

In addition, the analysis includes two indicators of the firm's innovative behavior, namely, degree of organization of R&D activities and R&D expenditures in order to discover whether there was new employment in innovative firms. Finally, the study considers variables related to the market due to the widely-accepted relationship between the market and innovation incentives. In this way, the paper analyzes three aspects of the competitive level: main market, market concentration, and internationalization level.

Table 1 here

This study uses different indicators of the innovation activity (Y_i) to discover the effect of the mobility of public researchers on the innovation process inputs and outputs (see Table 1 for the definition of these indicators). To establish the mean inputs of the process this paper uses the firms' total R&D intensity as an indicator that reflects the innovation effort and also the degree of commitment that the firm has in relation to R&D activities. Unlike other studies, this work subdivides the total R&D expenditures into external and internal expenditure and it constructs an indicator of the internal and external R&D intensity. The first indicator includes information concerning all the activities undertaken within a firm to generate technology, and the second, information regarding the external acquisition of technology. This last indicator recently acquiring significance due to the need to count on external sources of knowledge and also due to the possibility that firms have of profiting from economies of scale related to external organizations dedicated to research (Chadee and Pang, 2008; Den Hertog and Thurik, 1993).

In addition, the analysis includes propensity to patent. According to Czarnitzki and Licht (2006), despite the limitations that this indicator includes, the patenting propensity is a closer measure in time to the undertaking of R&D projects, compared to either the sales of new products or to the cost reduction achieved by applying new processes (Table 1 shows the definition of the variables).

RESULTS

Table 2 shows the results of the estimations of the probit model and the marginal effects obtained. This first part of the analysis shows that large firms, in high and medium technological sectors and with a high degree of organization of their R&D

activities show a greater propensity to hire public researchers coming from the public R&D system. The estimation of the marginal effects confirms that belonging to a high-tech sector and having a high degree of organization of the innovation activity could, ceteris paribus, increase the propensity to hire public researchers by about 3 and 2 percentage points, respectively.

Table 2 here

Firms in the high intensity technology sectors account for almost sixty per cent of the Spanish innovative activity. As a result, these firms have a higher propensity to seek different knowledge sources. In this case, firms that innovate hire public researchers to reinforce an existing research line or to increase the number of their innovative activities. These results coincide with the research of Hoils (2007), which shows that the concentration of innovative activity and the innovative environment are the major determinants of mobility.

The positive influence of the variable which measures the level of organization of R&D activities (i.e. whether the firm fulfils at least one of the following conditions: to have a department or commission for R&D, to have an R&D plan or to elaborate R&D indicators of the results) confirms the result of the work of Cruz-Castro and Sanz-Menéndez (2005). The assimilation of knowledge that scientific researchers transfer depends critically on the absorption capacity of the firm. Without such a capacity the firm will be unable to obtain economic benefits from scientific knowledge. What is more, the degree of organization of R&D activities in the firm facilitates interaction between scientific researchers and engineers from the R&D department to share knowledge, experiences and prospects in a useful atmosphere for knowledge transfer (Gold et al, 2001).

This study also finds that the greater the size of the firm is, the likelier the firm is to hire public researchers. This finding may come as a surprise if we bear in mind that public mobility support programs are basically geared to small firms. Nonetheless, empirical studies of recruitment in small firms could in part explain the low participation of those firms in the mobility support programs for personnel from the public to the private R&D sectors. These studies point out that small firms adopt informal practices of employment, resorting fundamentally to references or a network of personal contacts, instead of making use of more formal and impersonal practices, such as employment agencies, human resources trained in universities or public R&D programs (Aldrich and Langton, 1997; Barber, Wesson, Roberson, and Taylor, 1999; Henemann and Berkely, 1999; Pritchard and Fiedler, 1993; Ram, 1999; Van Auken, 2005). The reason that small firms undertake such informal practices is their shortage of funding (Leung, 2003; Ullah and Taylor, 2007) and the fact that small firms normally do not have a developed human resources activity. This implies that the probability of using and taking advantage of sophisticated recruitment and selection programs is diminished (Barber et al., 1999; Heneman and Berkley, 1999; Urbano and Yordanova, 2008).

Furthermore, the analysis of the profile of firms hiring personnel coming from the public R&D system provides highly interesting conclusions for policymakers. The mobility of public researchers does not stimulate the start of R&D activities for the first time in the firm. The study shows that non-innovatory firms do not hire public researchers, so these programs make no contribution to expanding the number of innovatory firms in the economy.

In the second part of the analysis directed toward estimating the effect of mobility, this paper provides evidence for the matching quality and also demonstrates that the balancing property is satisfied. Table 3 shows the findings of the tests applied to the means of the pre-treatment variables and the propensity score before and after matching.

Table 3 here

Before matching, the firms that hired and that did not hire public researchers are different in size, age, their belonging to high or low technology sectors and degree of organization of their R&D activities. After matching, these differences between the firms that hired and firms belonging to the control group disappear. So, data satisfy the methodological assumptions. Table 4 shows the average effect of the mobility on firms' innovation activity. In order to estimate the average effect, this study uses an area of common support which allows for the elimination of firms with poor levels of matching.

Table 4 here

The results of this research indicate that in the year in which mobility takes place firms increase their total R&D intensity by 2.55 percentage points compared to the firms that do not hire public researchers. In addition, the study reveals that in the same year mobility occurs, internal and external R&D intensity increases significantly. The internal R&D intensity grows by a higher proportion (hypothesis 1 is true). As a result, firms decide to increase the complementarity between these two sources of technology. Although the literature points out that the availability of external technology reduces internal R&D investment and therefore the firms' competitive advantage, recent studies provide arguments for the benefits of the complementarity between these two variables. So it is possible to capitalize on this complementarity in the event of having a certain amount of absorption capacity.

With regard to patenting propensity, results do not detect significant changes in the year mobility occurred, probably due to the fact that the public researcher is becoming acquainted with the routines of the organization and also with the R&D activities in his/her first year of joining the firm. Consequently, hypothesis 2 is not true in the year of mobility.

The analysis shows that mobility has simultaneous effects on the inputs and outputs only one year after the movement of the researcher is seen (hypotheses 1 and 2 are true in the year following mobility). These effects are positive and significant only in the cases of the internal R&D intensity and the propensity to patent. Apparently, the hiring of staff coming from the public R&D system could encourage firms to decide to maintain investments orientated toward internal technology generation compared to acquiring technology externally. With regard to patenting propensity, the results of this study confirm on the one hand, that a certain amount of time has to elapse before the mobility derived benefits become apparent, while, on the other hand, the analysis concerning the increase in propensity needs to take into account the profile of the firms benefiting from mobility. With regard to this last point, the present study shows that firms that take part in mobility belong mainly to the high-tech sectors. Firms in these sectors are more likely to patent even in the short run.

FINAL REMARKS AND CONCLUSIONS

This study analyses the mobility effects of personnel coming from the public R&D system on firms´ innovative processes. These human resources facilitate the transfer of knowledge previously developed and accumulated in the public R&D system to firms. This type of mobility study makes a contribution to understanding how scientific knowledge flows and is exploited by other agents in the innovation system.

The findings of this study confirm that scientific knowledge which public researchers provide has a positive influence on both inputs and outputs of the innovation process. The fact that firms have access to additional knowledge which is complementary to what they already possess represents a spur for exploiting and applying this new knowledge. Firms in this study continually increased their in-house R&D investments. As a result of these investments firms can create new knowledge of a unique and valuable type. The study shows that the effects of mobility are produced in large firms belonging to high-tech sectors and having a high degree of organization in their innovation activity. These results confirm that the assimilation of knowledge that public researchers transfer depends critically on the absorption capacity of the firm. In general, the findings of the study highlight the critical role that human resources and scientific knowledge play in firms' innovation activity, the findings also provide practical implications for firms and policy-makers.

Mobility makes it possible for firms to obtain potentially high-value knowledge. According to some authors, this knowledge has a great commercial impact and a positive influence on economic growth (Cohen et al., 2002; Griliches, 1984). Nonetheless, for firms to take advantage of this knowledge a certain absorption capacity must be developed (Cohen and Levinthal, 1990; Cruz-Castro and Sanz-Menendez, 2005), a fact which confirms the findings of this study. Recent literature points out that this capacity can improve if firms become more aware of the need to establish human resources practices with the aim of increasing their ability to administer, acquire, share and apply knowledge (Chen and Huang, 2009). Scientific knowledge has the characteristics of complexity and high tacit dimension (Bonache and Zarraga, 2008; Kaiser, 2002) and consequently, managing human resources is a key element to integrate scientific knowledge into the firm's stock of knowledge and to gain economic benefits. Transferring and integrating knowledge is not an automatic process and it may meet with resistance on the part of organization, thus making it difficult to integrate researchers and accept the knowledge they provide (Katz and Allen, 1982; Kessler et al., 2000). Exactly as the study shows, the effects of mobility on output begin to be visible some time after the researchers start to work with the firm, and managers must take this fact into account and should not expect to find positive performance in the short term when hiring R&D staff from the public system. To make scientific knowledge become firm-specific and be a source of competitive advantage for firms is a managing process which produces tangible results in the long term, so the decision to hire staff from the public system R&D must be regarded as a strategic one.

Acquiring knowledge through the mobility of researchers coming from the public R&D system clearly provides firms with an extra benefit. Taking on staff with proven scientific knowledge allows firms to reduce the inevitable uncertainty involved in the correct acquisition of any strategic factor (Amit and Schoemaker, 1993). In the case of human resources this uncertainty manifests itself in the difficulty involved in knowing in advance whether the performance of the individual, once selected, will meet expectations (Koch and McGrath, 1996). In this case, the question is whether the new scientific knowledge acquired will have positive effects on the firm's innovation activity. In this respect, there is a wide range of literature showing how much of a contribution to the innovation process (Laursen, 2002; Laursen and Foss, 2003; Leede and Looise, 2005) comes from highly qualified human resources. Public researchers, having received tuition and training in the public R&D system are concerned about the visibility of their productivity. And this, as the literature shows, impinges on mobility. The high skill level of these researchers and their very visible results could be of great use to the firm. So, the greater the knowledge the employer has of his potential candidates' available skills, as in this case, the better informed his selection decisions will be (Malm, 1954; Stigler, 1961), and, consequently, the less will be the uncertainty with regard to whether his choice was the right one or not.

The findings of this study also contribute to an improvement in awareness of how the innovation systems (SI) work, by providing evidence of the effect of relationships between agents of this system. Even though the literature provides broad recognition to the fact that the most important aspect taking place in an SI is the learning process of people (Lundvall, 1992), only a few studies analyze the contribution that human resources of the public R&D system make to SI and the industrial dynamic. This study shows that the contribution public researchers make to the innovatory process in firms is a positive one, although not all firms are taking full advantage of this mobility.

Being aware that the mobility of academic researchers takes place mainly toward large firms belonging to the high intensity R&D sectors is worthwhile for policy-makers. As a result, a number of aspects pertaining to the innovation activity of firms would be reinforced to the detriment of achieving a certain amount of technological diversity in the productive sectors. In addition, the continuous mobility of human resources toward innovative firms would only broaden and deepen the R&D activities of these firms and would not increase the number of innovative firms in the economy.

The usefulness of this scientific knowledge to economic progress and technological change is amply documented. Governments are interested in having staff mobility from the public R&D system in order for firms to be able to access this knowledge. Nonetheless, many of the programs supporting the mobility of scientific personnel to firms are not acquainted with the interaction that takes place between the public and private R&D sectors. Future lines of research could be geared to establishing the impact of mobility on a broader number of aspects of firms' innovation activity and this could even go beyond R&D activities. To discover how firms gain an edge from scientific knowledge is a determining factor, particularly, in the degree of innovation novelty and economic return. Moreover, future researchers should take into account that public investigators do not only pass on knowledge but also new skills and organizational practices. The above could be of importance for firms and policymakers to obtain information about the factors that influence on the integration process of scientific knowledge to the firm's stock of knowledge and organizational routines. Finally, since the sub-system of human resources is a differentiating element of innovation systems, comparative studies among countries on the effectiveness of mobility could help to improve the design of technology policies and allow to analyze the flows of scientific knowledge in the global economy.

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Table 1. Description of the variables used in the study

Treatment variable	
Mobility (M)	1 indicates if the firm hired personnel coming from the public R&D system
Variables used to estimate the causal effect	
Internal R&D Intensity	Rate between the internal R&D expenditures and sales
External R&D Intensity*	Rate between the external R&D expenditures and sales
Total R&D Intensity*	Rate between the total R&D expenditures and sales
Patent Propensity*	Rate between the patents and the employees
Variables used to estimate the propensity score	
Size*	Log of employees in the year 1999
Age*	Log of age of the firm in the year 1999
High-tech sector	1 indicates that the firm belonged to this sector in the year 1999 (NACE: 24, 30, 32, 33, 35)
Mid-tech sector	1 indicates that the firm belongs to this sector in the year 1999 (NACE: 16, 25, 27, 29, 31, 34)
Region*	1 indicates that the firm was located in a central region (Catalonia, Madrid, Basque Country) in the year 1999
% of Foreign Capital	Percentage of foreign capital participation in the year 1999
Degree of organization of R&D activities	1 if the firm fulfils at least one of the following conditions; have a department or commission for R&D; have an R&D plan; elaborated R&D indicators of the results
R&D expenditures	1 if the firm had R&D expenditures in the year 1999
Growing markets	1 if the firm considered its main market as growing in the year 1999
Market concentration	1 if the firm reported that its main market consisted of fewer than 10 competitors in the year 1999
Export propensity*	Rate between exports and sales in the year 1999

*variables that were constructed based on the survey; the rest of the variables appear as in the survey. Website of survey: http:// www.funep.es

Table 2. Estimation results of the probit model and marginal effects

Variables†	Coef.	M.E.
Size	0.24***	0.01***
Age	-0.01	
High-tech sector	0.55**	0.03**
Med-tech sector	0.35*	0.01*
Region	-0.13	
% of Foreign Capital	-0.01	
Degree of organization of R&D activities	0.37**	0.02*
R&D expenditures	-2.24	
Growing markets	0.04	
Market concentration	0.11	
Export propensity	-0.01	
N		
Log Likelihood		
Pseudo R^2		
Correctly classified		

† All variables are lagged one year
M.E.= Marginal Effects
***significant at 1 percent; ** significant at 5 percent; * significant at 10 percent.

Table 3. Comparisons of means between firms that hired and did not hire public researchers (before matching) and between that hire public researchers and the control Group (after matching)

Variables	Mean of firms that hired	Mean of firms that did not hire	Mean of control group
Size	5.79	4.54***	5.63
Age	5.05	4.43*	3.92
High-tech sector	0.39	0.20**	0.37
Mid-tech sector	0.42	0.39	0.47
Low-tech sector	0.18	0.41**	0.17
Region	0.52	0.46	0.37
% of Foreign Capital	30.88	21.92	41.16
Growing markets	0.39	0.39	0.43
Market concentration	0.69	0.57	0.67
Export propensity	27.15	20.46	28.92
Degree of formalization of R&D activities	0.58	0.22***	0.57
R&D expenditures	536.73	160.22	386.36
Propensity score	0.07	0.02***	0.06
N	35	460	35

Note: Significances (***significant at 1percent; ** significant at 5percent; * significant at 10 percent) indicate that the means compared differ according to the two tailed t-test for continuous variables and Fisher exact test dichotomic variables.

Table 4. Average effect of the mobility of public researchers from the public R&D system to firms

	Means of firms that hired	Means of firms that did not hire	Causal Effect (Percentage Points)	Bootstrap standard error	N
		t period			
External R&D Intensity	1.10	0.18	0.92***	2.52	70
Internal R&D Intensity	2.30	0.67	1.63***	2.22	70
Total R&D Intensity	3.40	0.85	2.55***	2.87	70
Patent Propensity	0.01	0.00	0.01	1.35	70
		t+1 period			
External R&D Intensity	0.53	0.12	0.41	0.36	70
Internal R&D Intensity	1.80	0.41	1.39***	2.48	70
Total R&D Intensity	2.33	0.53	1.80	1.24	70
Patent Propensity	0.48	0.00	0.48**	1.91	70

***significant at 1 percent; ** significant at 5 percent.