THE PHD LABOUR MARKET AND THE INNOVATION PERFORMANCE ALONG OECD MEMBERS

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Abstract

R&D is essential for competitiveness in a global economy and doctorate holders constitute a vital human resource in the research private sector. However, in the recent literature little attention has been paid to measure the doctorate's employment in the private sector, their role in the public-private research linkages and their effects on the innovation performance of the countries. The recruitment of PhD graduates in the private sector should be considered a key avenue in converting publicly funded basic research into commercialized innovations, technological progress and productivity growth. The aim of this contribution is to examine and measure which policymakers are boosting the PhD employment especially in the business sector and how these policies affect the R&D and innovation performance of the countries. Our findings suggest that the supply of new PhD graduates is highly correlated with the business expenditure on R&D and their employment in the private sector is crucial to increase the knowledge-intensity of the labor force in view of enhancing economic competitiveness and addressing societal changes. We conclude that most of the countries need to reform government policymakers focusing on R&D expenditures in the business sector to boost the qualified employment of doctorate holders.

Keywords: R&D, employment of PhD holders, doctorates in the private sector, innovation policymakers, OECD.

1 INTRODUCTION

The Innovation Union Competitiveness report published by the European Commission in 2011 highlights the need of additional one million researchers in the private sector to increase the investment of the EU in R&D to 3% of GDP in 2020, see [1]. Thus, in view of 2020 it is crucial to increase the knowledge-intensity of countries' labour force, and in particular to increase the share of researchers in the business sector. The number of researchers (full time equivalent) in the OECD area has risen to 25% over the period 1999-2007, and 35% in the EU-2, see [2]. However the researchers employed in the business sectors do not follow the same pattern. In the OECD, they have increased 24% between 1999 and 2007 and around 32% in the EU-27. Moreover, 63.71% of researchers (full time equivalent) in the OECD were employed in the business enterprise sector in 2007, the same proportion than in 1999 (64.33%). For the EU-27, 45.90% of researchers were employed in the business sector in 2009, a percentage slightly lower than in 1999 (47.12%). In terms of stock of researchers countries are concerned about the importance to increase their knowledge-intensity, but in terms of in-flow, countries should develop new policies to increase the number of researchers employed in the business sector for R&D. Moreover, the role played by the Higher Education institutions is crucial as providers of specialized professionals developing an 'industry-relevant' research portfolio and PhD graduates which fit industry's needs.

Although there are signs in the considerable increase in new tertiary education and doctoral graduates, the large stock of researchers are not being employed in the business sector. Data from the project launched by the OECD in collaboration with the UNESCO Institute for Statistics (UIS) and Eurostat (OECD/UIS/Eurostat CDH project), (see [3]), reveals than in 2009, on average, 12.1% of doctorate holders employed as researchers was working in the business enterprise sector, 22.7% in the government sector, 61.5% in the higher education sector and 3.5% in the private non-profit sector[1]. By contrast, in countries such as Belgium, Netherlands, Norway and United States, the percentage of doctorate holders employed as researchers working in the business enterprise sector in 2009 was from 21% in Belgium to 35% in the United States. Fig.1 shows the distribution of the researches employed in OECD countries by sector, in 2011. Note that the highest presence of researchers employed in the private sector corresponds to the leading countries in research and innovation, i.e., United States, Korea, or Japan exceeding the overall OECD rate, followed by Austria, Denmark and Sweden.

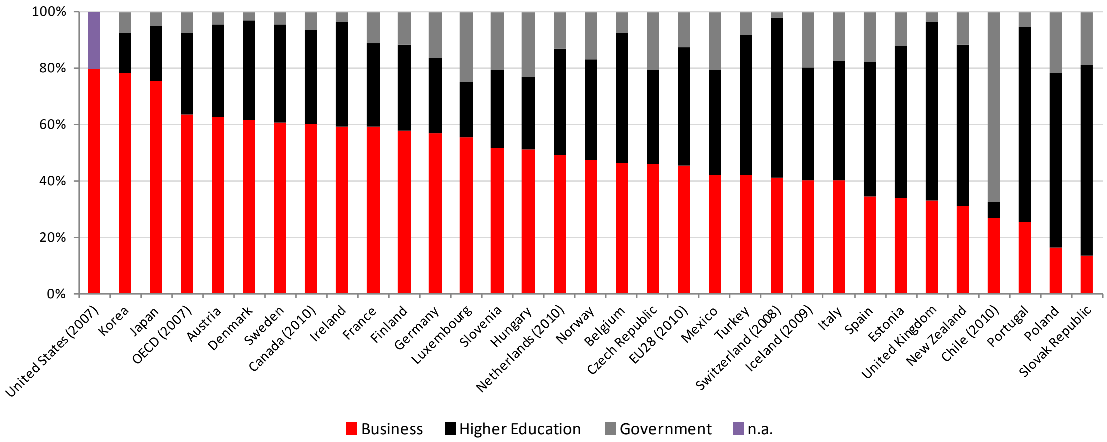

Figure. 1. Researchers employed in OECD countries by sector, in 2011.

On the other hand, although literature suggests the important role of expenditure in R&D (public and private) the outcomes and benefits of R&D investments depend not only on the amount of funding but also on the sources of support and the type of R&D that those sources support. For OECD countries, Gross Domestic Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP) in 2009 was 2.41% and the percentage of GERD financed by industry was 60.23%. Moreover, the Business Expenditure on R&D (BERD) as a percentage of GDP for OECD countries in 2009 was 1.61%, although in countries like Finland, Japan, Korea and Sweden the private expenditure on R&D exceeds 2.5% of GDP. Fig.2 shows the Gross Domestic Expenditure on R&D (GERD) as a percentage of the Gross Domestic product (GDP) in OECD countries, by sector, in 2011. Note that the GERD corresponding to the private sector exceeds the 2% of their GDP for R&D leading countries.

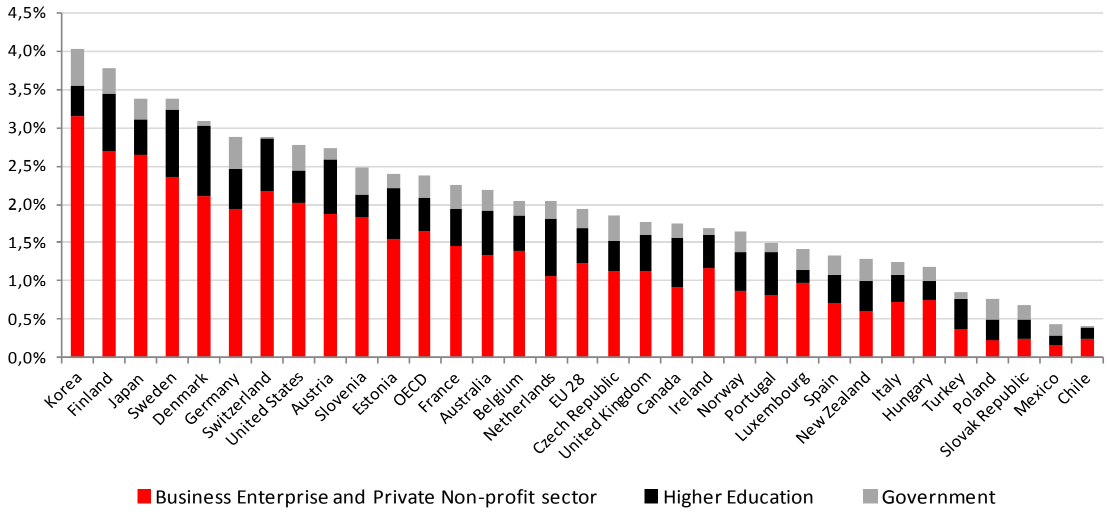

Figure. 2. Gross Domestic Expenditure on R&D (GERD) as a percentage of Gross Domestic product (GDP), by sector, in 2011[2].

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[1] European Comission (2010).

[2] Source: OECD (2012), Science, Technology and R&D Statistics. Main Science and Technology Indicators.

Naturally some questions arise. What is the impact of business expenditure on R&D on the employability of PhD holders in the private sector and therefore on the innovation performance of countries? What are the public policies that are boosting the business expenditure on R&D and, naturally, the employment of doctorate holders in the private sector? Are the leading countries in innovation promoting the new doctorate graduates as human capital specifically trained to conduct research and convert scientific knowledge into a new product, service or technology?

This pioneer study contributes in understanding and quantifying the relationships between new doctorate graduates, funding and investment in R&D, innovation capacity of firms and outputs of research and innovation. We found out that business expenditure on R&D and new doctorate graduates play a key role for creating skilled employment for driving innovation. Moreover, for the analyzed countries, the direct or indirect government funding for private expenditure on R&D through R&D tax incentives have strong effects on business expenditure on R&D, and hence on the employability of PhD holders in the private sector.

2 DISCRIMINANT FACTORS OF R&D IN OECD COUNTRIES

R&D investment collects the set of creative activities developed in a systematic way in order to increase the stock of knowledge as well as to conceive new applications of existing knowledge. The basic input of innovation is investment in research and development (R&D), although there are other innovative activities which may be even more important, such as purchases of technology or equipment, learning by doing, etc. It is important to note that countries at the top of the ranking on expenditure on R&D share a big gap between the private and public R&D intensity, in 2011. R&D leaders, Korea, Japan, Finland, Sweden, Switzerland, United States and Denmark, have a key role of business activity. Germany follows a similar pattern. Countries with a strong presence of the public sector like Canada, Portugal, Norway and Spain invest practically the same in the public than in the private sector.

A key issue is that the research activity in the private sector in Europe is lower than in OECD countries as it is shown in Fig.1. This, combined with a lower investment on business R&D, makes Europe has strong competitors like Korea, Japan or United States. One of the major obstacles for investment in business R&D and therefore to absorb a greater number of researchers is due to funding. It is well known that the share of gross domestic expenditure on R&D (GERD) financed by the public sector is typically large in less research-intensive countries. In the OECD countries, around 60.3% of the GERD in 2011 was financed by the industry, 31.1% by the Government and only a 5.2% by other public funds. However, in the most research-intensive countries, the business sector is the predominant source of funds, around 75% of R&D funds (see for instance [4] and references therein).

Each country has its own research and innovation system. However, it is generally accepted that well-functioning systems share a number of key indicators: high levels of gross domestic expenditure on R&D (GERD) and business expenditure on R&D (BERD), higher investment on private R&D than public R&D (government and higher education), basic research developed by the private sector, private R&D financing and a high level of researchers working in the private sector.

For a deeper understanding of the driving forces that make countries top innovation leaders and trying to figure out the role of PhD graduates in these countries, Fig.3 displays two-dimensional view of this set of key indicators obtained by using a statistical method called Factor Analysis[3]. The horizontal axis represents the first factor and the vertical axis the second factor. Table 1 shows the factor's coefficients (these factors explain 94% of the variability of the data set).

[3] Factor Analysis is a statistical method used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors (linear combinations of the original variables). Factor analysis searches for such joint variations in response to unobserved latent variables. Factor analysis is related to principal component analysis (PCA), but the two are not identical. Latent variable models, including factor analysis, use regression modeling techniques to test hypotheses producing error terms, while PCA is a descriptive statistical technique.

Table1. Factor's coefficients.

Indicator[4]	Factor1	Factor2
Gross domestic expenditure on R&D (GERD)	0.882	0.396
Business expenditure on R&D (BERD)	0.928	0.342
Difference between private and public investment on R&D	0.939	0.231
Private R&D financing	0.946	0.011
Proportion of Researches in the Business Enterprise sector	0.940	-0.027
New PhD graduates[5]	0.114	0.983

From Table 1 one can observe that the first factor (Factor1) is related to the overall magnitude of investment in R&D, the private sector funding and the employability of researchers. The second factor (Factor2) is concentrated on the production of new PhD graduates. As a first conclusion, we find out that the private sector activity in terms of expenditure, financing and employment of researchers is able to classify the analyzed countries. The second conclusion is the potential that new doctorate graduates present to discriminate the research and innovation performance along OECD members.

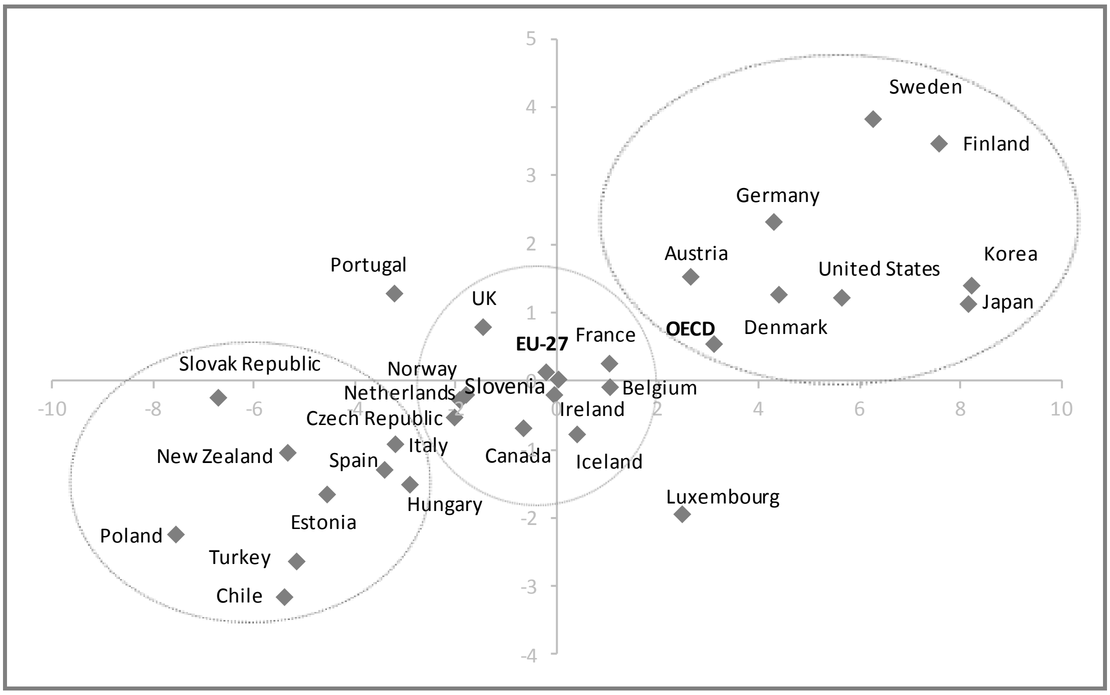

Figure. 3.Two-dimensional view of R&D indicators for OECD countries in 2009.

These results show that, based on the selected indicators in terms of skilled human resources, investment in R&D and financing, OECD countries are positioned in three clusters. Sweden, Finland, Korea and Japan are the top-four leader countries in innovation, followed by United States, Denmark and Germany. Moreover, Sweden and Finland have also the higher rates of new PhD graduates.

[4] The indicator *Percentage of basic research developed by the private sector* is not included in the analysis due this data is not available for a large set of countries.

[5] New doctorate graduates (ISCED6) per 1000 population aged 25-34 in 2009. Source: Eurostat.

The employability of researchers in the business sector, specifically, doctorate graduates, is evidenced as a determinant of the position reached by the countries in terms of R&D. They are highly qualified employers outside academia as providers of new knowledge, strengthen the collaboration between the private and public sector and act as partners in international collaborations between different institutions and companies, raising the countries competitiveness. However, funding and investment in R&D are factors that also contribute to these differences between countries.

Fig.4 shows the two-dimensional view of R&D indicators for OECD countries in 2011, see [5]. First, note the spectacular improvement of Korea, basically due to the increase on the second Factor, i.e., PhD production. The same effect happens in Japan. It is also remarkable the increasing differences between OECD average and EU28.

Figure. 4.Two-dimensional view of R&D indicators for OECD countries in 2011.

3 PHD GRADUATES AND OUTPUTS OF RESEARCH AND INNOVATION

The absence of data on doctorate holders employed in the business sector, leads to the identify *employment in knowledge-intensive activities* as a measurable indicator of driving innovation[6]. By using econometric models identify that the production of new PhD holders have a strong effect on employment in knowledge-intensive activities, more than tertiary education graduates, for European countries in 2009. Moreover, we analyze the effect of different R&D indicators on employment in knowledge-intensive activities. Table 2 shows a description of the variables analyzed and Pearson's correlations are shown in Table 3.

[6] This indicator is only available for European countries. Source: Eurostat.

Table2. R&D indicators

Indicator[7]	Definition
Employment in knowledge-intensive activities as percentage of total employment.	Number of employed persons in knowledge-intensive activities in business industries. Knowledge-intensive activities are defined based on EU Labour Force Survey data, as all NACE Rev.2 industries at 2-digit level where at least 33% of employment has a higher education degree (ISCED 5 or ISCED 6). Knowledge-intensive activities provide services directly to consumers. Such as telecommunications, and provide inputs to the innovative activities to other firms in all sectors of the economy.
New doctorate graduates per 1000 population aged 25-34	Graduation rates at doctorate level (ISCED 6) as a percentage of population in reference age cohort.
Percentage population 30-34 having completed tertiary education	Number of persons in age class with some form of post-secondary education (ISCED 5 and 6)
International scientific co-publications per million population	Number of scientific publications with at least one co-author based abroad, where abroad is non-EU for the EU27.
R&D expenditure in the public sector as percentage of GDP	All R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD).
R&D expenditure in the private sector as percentage of GDP	All R&D expenditures in the business sector (BERD).
Non R&D innovation expenditures as percentage of turnover	Sum of total innovation expenditures for enterprises, in thousand Euros and current prices excluding intramural and extramural R&D expenditures
Public-private co-publications per million population	Number of public-private-co-authored research publications. The definition of the "private sector" excludes the private medical and health sector. Publications are assigned to the country/countries in which the business companies or other private sector organizations are located.
PCT patent applications per billion GDP	Number of patent applications filed under the PCT, at international phase, designating the European Patent Office (EPO). Patents counts are based on the priority date, the inventor's country of residence and fractional counts.
High-tech product exports	Share of exports of all high technology products of total exports. High Technology products are defined as the sum of the following products: Aerospace, Computers-office machines, Electronics-telecommunications, Pharmacy, Scientific instruments, Electrical machinery, Chemistry, Non-electrical machinery, Armament. The total exports for the EU do not include the intra-EU trade.
License and patent revenues from abroad as percentage of GDP	Export part of the international transactions in royalties and license fees. Trade in technology comprises four main categories: Transfer of techniques (through patents and licenses, disclosure of know-how); Transfer (sale, licensing, franchising) of designs, trademarks and patterns; Services with a technical content, including technical and engineering studies, as well as technical assistance; and Industrial R&D. TBP receipts capture disembodied technology exports.

[7] Source: Innovation Union Scoreboard 2011. Eurostat.

Table 3. Pearson' correlations

R&D Indicators	1	2	3	4	5	6	7	8	9	10	11
1 New doctorate graduates	1										
2 Population completed tertiary education	0.267	1									
3 International scientific co-publications	0.632*	0.709*	1								
4 Public-private co-publications	0.701*	0.585*	0.911*	1							
5 Employment in knowledge-intensive activities	0.512*	0.581*	0.791*	0.682*	1						
6 R&D expenditure in the business sector	0.785*	0.460*	0.782*	0.826*	0.695*	1					
7 R&D expenditure in the public sector	0.697*	0.551*	0.740*	0.785*	0.484*	0.837*	1				
8 Non R&D innovation expenditure	-0.278	-0.012	-0.209	-0.348	-0.069	-0.273	-0.395*	1			
9 PCT patent applications	0.747*	0.524*	0.808*	0.893*	0.700*	0.931*	0.851*	-0.257	1		
10 High-Tech product exports	0.056	0.035	0.195	0.164	0.552*	0.208	0.009	0.153	0.251	1	
11 License and Patent revenues from abroad	0.548*	0.451*	0.690*	0.754*	0.688*	0.646*	0.535*	-0.105	0.793*	0.403*	1

* Significant at 5% level

One can observe that *employment in knowledge-intensive activities* is positively correlated with all the indicators except *Non R&D innovation expenditure*. Thus, we have tested a number of linear regression models explaining *employment in knowledge-intensive activities* as dependent variable in terms of the R&D indicators. Table 4 reports the models of greater interest.

Table 4. Analysis of the indicators that influence *Employment in knowledge-intensive activities*

Dependent variable: Employment in knowledge-intensive activities

	Model1	Model2	Model3	Model4	Model5	Model6	Model7	Model8	Model9	Model10
	Coefficient									
Intercept	4.892*	7.731*	14.344*	-6.653*	6.537*	5.470*	-7.047*	7.043*	4.222*	10.825*
New doctorate graduates	3.119*	-0.499		1.219*	1.022*	2.012*			0.356*	
Population completed tertiary education	0.087*	0.040				0.074*			0.067*	
Log Internatinal scientific co-publications				2.784*			2.973*			
Log Public-private co-publications					1.467*			1.328*	1.146*	
R&D expenditure in the business sector		3.659*	5.899*				0.827**	1.249*		
R&D expenditure in the public sector			-10.929*							
Log PCT patent applications										2.019*
High-tecnology product exports						0.163*			0.1816*	
Licence and Patent Revenues from abroad										1.443*
$\overline{R}^2$	0.75	0.78	0.65	0.84	0.83	0.77	0.89	0.85	0.83	0.87

*Significant 5% level

**Significant 10% level

From Model 1, a strong positive relationship between *employment in knowledge-intensive activities* and n*ew doctorate graduates* is identified. It implies that PhD holders play an essential role as a source of highly skilled human resources. Thus, ongoing we identify these two variables as follows. The estimated coefficient (3.119) suggests that an increase in one unit of new doctorate graduates implies an increase of 3.2 units of employment in knowledge-intensive activities. That is, for every new doctorate graduate (one per 1000 population aged 25-34) the employment in knowledge-intensive activities (as percentage of total employment) increases 3.2%. Hence, an increase in knowledge-intensive activities will provide greater inputs to the innovative activities of firms in all sectors of the economy. This is further supported by our findings from Figs. 3 and 4 where leader countries in innovation show the highest rates of new doctorate graduation. Notice that in presence of n*ew doctorate graduates*, tertiary education has almost no effect on employment (the estimated coefficient is 0.087).

Analyzing the expenditure on R&D, as one can expect, the private investment on R&D has a strong positive effect on employment in knowledge-intensive activities (Model 2). It explains almost 80% of the variability of the data. The presence of this variable causes that *new doctorate graduates* results not significant at 10% level. Notice that the correlation coefficient between *new doctorate graduates* and *business R&D expenditure* is 0.785 (Table 3).

Model 3' estimation provides interesting features showing that *public expenditure on R&D* has a negative effect on the employment in knowledge-intensive activities. We find of interest to analyze this unexpected negative coefficient (-10.929) corresponding to the variable R&D expenditure in the public sector (government sector + higher education sector), i.e., $GOVERD\&HERD$. Model 3 can be written as follows

$$Employment = 14.34 + 5.89\, BERD - 10.92\ GOVERD\&HERD$$

Equivalently and according to Table 4, we can consider that 65% of the variability of the Employment can be explained by the following model

$$Employment \approx 14 + 6\, BERD - 11\, GOVERD\&HERD$$

Now, in terms of the Employment, what is the effect of expending 1% of the GDP in R&D in the public sector (government sector and Higher education)? In the presence of BERD, the estimated effect is not positive at all! In fact the effect of $GOVERD\&HERD$ on the Employment is negative. But, if we consider simultaneously expenditures in $GOVERD\&HERD$ and expenditures in BERD we can obtain a compensating effect that can be evaluated as follows. Let consider $BERD = 2\, x\, GOVERD\&HERD$. Thus, Model 3 can be written as

$$Employment \approx 14 + (6x\ 2 - 11)\, x\, GOVERD\&HERD\ \approx 14 + GOVERD\&HERD$$

According to this equation we can conclude that, to produce one unit of increase in the employment in knowledge-intensive activities by expending one unit in the *public expenditure on R&D* it requires compensating its negative marginal effect by expending two units in *R&D in the business sector.* This result reveals that high R&D intensive countries are characterized by a high expenditure of the private sector. According to Figure 2, we can observe that countries leaders in innovation, as Finland, Sweden, Korea, Japan, Denmark, Switzerland, Germany, United States and Austria shows the higher levels of private expenditure on R&D and the biggest differences between private and public investment on R&D. Hence, the empirical evidence shows that to raise the countries' productivity measured as the employment in knowledge-intensive activities, it is crucial to increase the business expenditure on R&D. Although the business expenditure on R&D is highly correlated with the involvement of the private sector in the financing of domestic R&D activities, governments play a key role in financing the business expenditure on R&D, as we will discuss later.

The estimation of models 4, 5, and 6 show that the presence of the number of scientific publications with at least one co-author based abroad (*International scientific co-publications*), the number of public-private co-authored research publications (*Public-private co-publications*) and the *High-technology product exports* may have moderate positive effects on the *employment in knowledge-intensive activities*. International scientific co-publications are a proxy for the quality of scientific research as collaboration increases scientific productivity. Moreover, it is one of the most common indicators used to measure the output of R&D. Consistently with our expectations higher score on the quality of scientific research implies a 2.78% higher employment in knowledge-intensive activities. Also, every 1% increase in the high-technology exports rises 0.16% the employment in knowledge-intensive activities. From Model 5 we learn that the number of public-private co-authored research publications has a strong and positive effect on employment. This indicator captures public-private research linkages and active collaboration activities between business sector researchers and public sector researchers resulting in academic publications. Therefore, this indicator provides one relevant way to measure if public funds are turned into industry-relevant research. Moreover, this cooperation from the private sector is only feasible with the existence of employment in knowledge-intensive activities, and therefore, if doctorate graduates are employed in the private sector. Thus, when the public-private co-publications increase in one unit the employment in knowledge-intensive activities increase 1.47%. This effect is somehow smaller than the effect of the international scientific co-publications on employment. Models 4 and 5 achieve a goodness of fit of 83% and 84%, respectively.

From Model 10 we find out that the *number of patent applications filed under the PCT* (per billion GDP) and *the license and patent revenues from abroad* (as percentage of GDP) have strong and positive effect on employment in knowledge-intensity activities. Patent data provides one relevant way to measure if public funds are turned into technologies with potential to be commercialized. In this sense, one unit increase (in logarithmic scale) in the number of patent application filed under the PCT (per billion GDP) implies an increase of 2.02% on employment in knowledge-intensive activities, as well as the one unit increase in the license and patent revenues from abroad (as percentage of GDP) implies an increase of 1.44% on employment in knowledge-intensive activities. As one can expect, as revenues from abroad increase through the transfer of technology (licenses and patents) as a major source of income, increase the private investment on R&D and in consequence, the level of highly qualified employment. It is important to notice that the use of GDP as the common denominator implies a need to refer to the size of the country as well as its economic growth.

4 CONCLUSIONS

After Section3 we can conclude that *business expenditure on R&D* is one of the main factors influencing the employment of PhD holders in the private sector, by contrast to *public expenditure on R&D* (government and higher education). Government' policies have to consider these effects and design consequently their strategies. Other variables related with the R&D performance of countries that present significant positive effects on PhD labour market are: *International scientific co-publications*, *Public-private co-publications, Patent applications filed under the PCT*, *High-technology exports* and *License and patent revenues from abroad*. It means that policies designed to incentive the production of this research and technology outputs will indirectly enhance the high quality PhD employment.

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