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HOW TO BOOST THE PHD LABOUR MARKET? FACTS FROM THE R&D AND INNOVATION POLICIES SIDE

Mónica Benito and Rosario Romera[a,b]

Abstract

This paper analyzes the PhD labour market in connection to the Research and Innovation countries' performance. Research and Innovation is essential for competitiveness in a global economy and doctorate holders have the skills and attributes to both engage in world-class research and make productive contributions in a wide spectrum of professional roles in innovation, in particular, in the 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 paper is to **examine which policies are boosting the PhD employment especially in the business sector** and **how these policies affect the research and innovation performance of the countries**.

Keywords: Business expenditure on R&D; Government funding; Highly qualified labour force; Innovative SMEs; PhD; Private sector; Research and Innovation;

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How to boost the PhD labour market? - Facts from the R&D and innovation policies side

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Abstract

This paper analyzes the PhD labour market in connection to the Research and Innovation countries' performance. Research and Innovation is essential for competitiveness in a global economy and doctorate holders have the skills and attributes to both engage in world-class research and make productive contributions in a wide spectrum of professional roles in innovation, in particular, in the 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 paper is to **examine which policies are boosting the PhD employment especially in the business sector** and **how these policies affect the research and innovation performance of the countries**.

1. Introduction

Investment in research and innovation is a key driver of economic growth and national competitiveness. This is why increasing investment in Research and Development (R&D) is one of the five priorities of the Europe 2020 strategy[1]. More than ever it is necessary to identify different series of determinants of firm innovation capacity. An abundant literature have analyzed the effects of public support schemes on firms' innovation (Fier, 2002; Falk, 2004; Czarnitzki et al. 2004; Ebersberger and Lehtoranta, 2005; Busom, 2000; European Comission, 2003; Dutch et al., 2007; Hall, B.H. and J. van Reenen, 2000). Other studies focused on the impact of linkages between firms and public research institutions on the process of firm's innovation (Aghion, P. et al. 2008; Cohen, W.M. et al, 2002; Lacetera, N. 2009; Hall, B.H. et al. 2003; Veugelers, R. and B. Cassiman, 2005; Lacetera, N. 2005). Nevertheless, when assessing the impact of different strategies on firm innovativeness, there is a gap regarding the impact of PhD holders as vital capital human resource to raise the private sector's research on firms' innovation and countries' competitiveness.

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. But, what percentage of PhD graduates is needed to boost the business investment in R&D and increase the innovation performance of

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[1] European Comission, 2010.

firms?. 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) 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[2]. 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 (see Benito and Romera, 2013).

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 (David, P.A. et al, 2000; Von Tunzelmann, N. and Martin, N. 1998; Link, A. 1982; Levy, D.M. 1990). For OECD countries, the Gross Domestic Expenditure on R&D (GERD) as a percentage of 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.

Naturally raises some questions. 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?

There is a need to understand and quantify the relationships between new doctorate graduates, funding and investment in R&D, innovation capacity of firms and outputs of research and innovation. In this study 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. However, the European innovation leaders do not need government support to private R&D for the good performance of their innovation systems.

This paper is organized as follows. Section 2 provides a short description of key indicators in research and innovation systems for OECD countries in 2009. By using multivariate statistical techniques we identify the factors that explain the differences in R&D between countries and generate a map with three clusters. One of the most important factors is the production of new doctorate graduates. In Section 3, by using econometric models, we identify the most influential indicators in the creation of skilled jobs, specifically in the private sector, for European countries in 2009. In Section 4 we explore the relationships between government funding for

[2] OECD/UNESCO Institute for Statistics/Eurostat data collection on careers of doctorate holders 2010.

R&D, business expenditure on R&D, PhD graduates and outputs of research and innovation. Finally, section 5 gives some conclusions and policies recommendations.

2. Which are the main drivers of innovation?

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. 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. For OECD countries, the *Gross Domestic Expenditure on Research and Development* (GERD) accounted 2.41% of GDP (*Gross Domestic Product*) in 2009, slightly 11% more than in 1999 (2.16% of GDP in 1999). 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 those sources support. Figure 1 shows the GERD as a percentage of GDP by institutional sectors (Higher Education, Government and Private sector) in 2009.

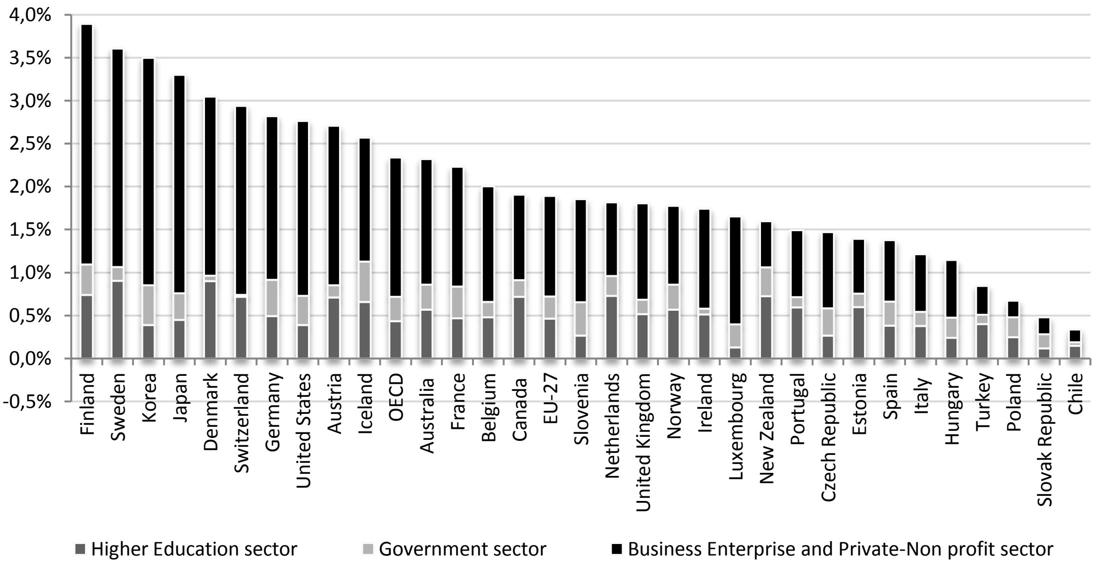

Figure 1. Gross Domestic Expenditure in R&D (GERD) as a percentage of GDP by institutional sectors, 2009[3,4]

In the OECD area, in 2009, the private sector spending on R&D accounted for 1.62% of GDP (1.49% in 1999), which represent an increase over the last decade of 7%. Government and university spending on R&D accounted for 0.29% and 0.44% of GDP respectively, a share that has increased 9% and 26% over the last decade (0.27% and 0.35% in 1999). By contrast, the increase in business expenditure on R&D between 1999 and 2009 in Finland, Japan and Korea was 30%, 20% and 70%, respectively. These data reveals the considerably increase in the private sector for R&D leaders respect to other countries.

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. Figure 2 shows the difference (in percentage points) between the private and public investment on R&D in 2009. It is clear that all R&D

[3] OECD Science, Technology and R&D Database and UNESCO Institute of Statistics, 2011
[4] Data on R&D by institutional sectors for Australia, Chile, Iceland and Switzerland for 2008

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. Other countries invest more in the public sector than in the private sector, which suggests a bad linkage between R&D investment and innovation performance.

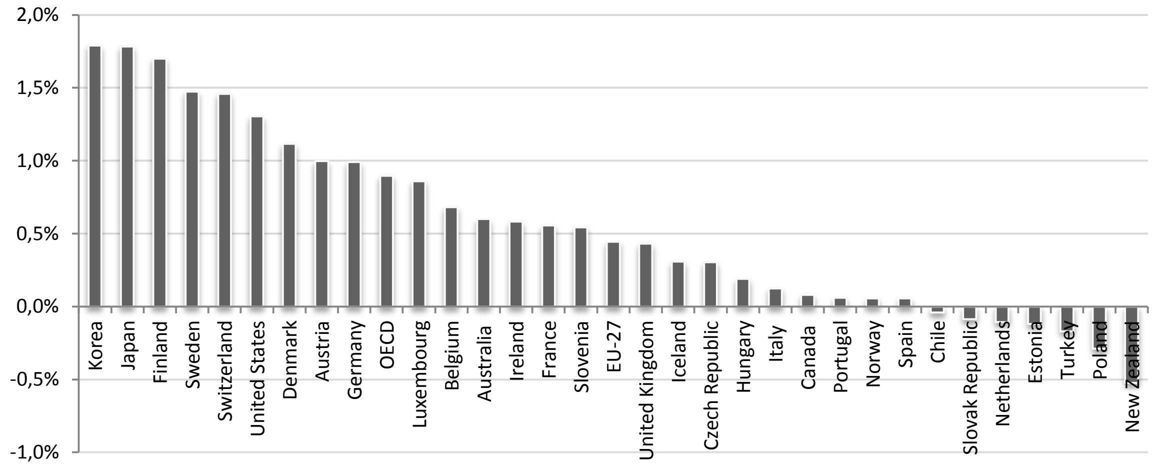

Figure 2. Difference between private and public expenditure in R&D, 2009.

The importance of universities as providers of new knowledge and as trainers of researchers and other highly skilled workers has contributed to the widespread budgetary prioritization of public R&D funding. In most countries, university basic research accounts for more than 50% of all basic research performed in the country. For countries where data was available, Figure 3 shows the basic research performed as a percentage of national basic research by institutional sectors in 2007. One can observe that countries at the top of the ranking on expenditure in R&D (Korea, Japan, Switzerland and United States) share that more than 30% of all basic research is performed by the private sector.

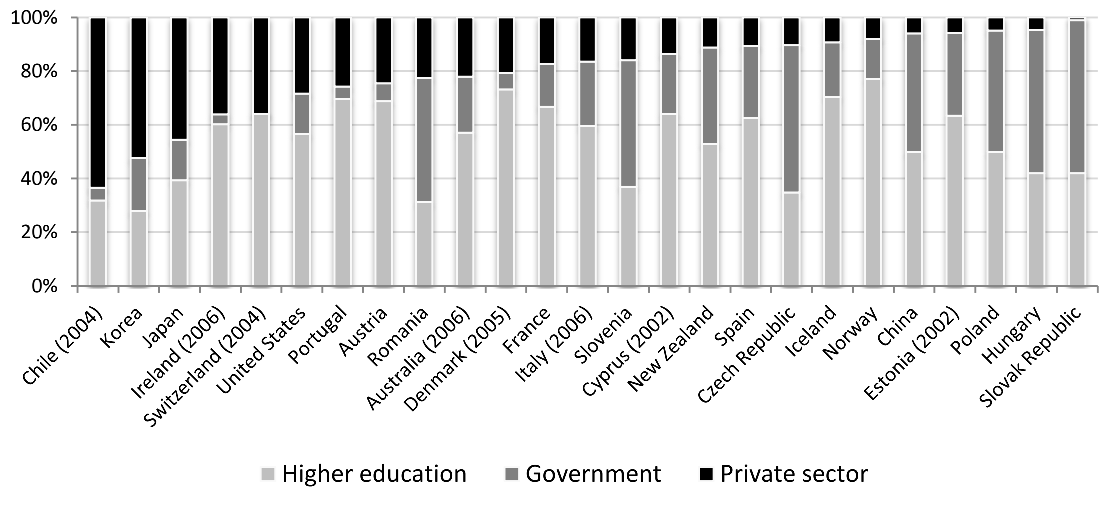

Figure 3. Basic research performed as a percentage of national basic research by institutional sectors 2007[5].

[5] OECD Research & Development Database, December 2009

A good balance is the collaboration between public research institutions and private institutions (business, industry) to avoid the decrease in industrial-based research. In this sense, PhD graduates play an essential role to encourage greater intellectual interchange between industry and academia. Types of links between universities and firms are mentioned in Benito and Romera (2013) and references therein.

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-27. 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%). Figure 4 shows the researches employed by institutional sectors in 2009. 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.

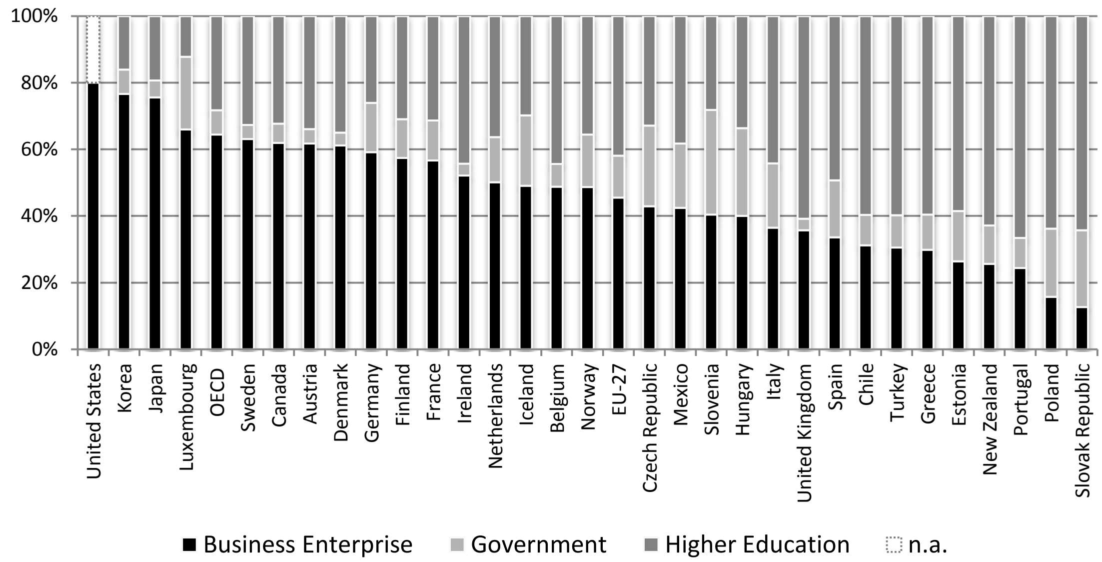

Figure 4. Researchers employed by institutional sectors, 2009[5].

A key finding is that the research activity in the private sector in Europe is lower than in OECD countries. 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 2009 was financed by the industry, 31.2% by the Government and only a 5.2% by other public funds (see Figure 5). However, in the most research-intensive countries, the business sector is the predominant source of funds (around 75% of R&D funds).

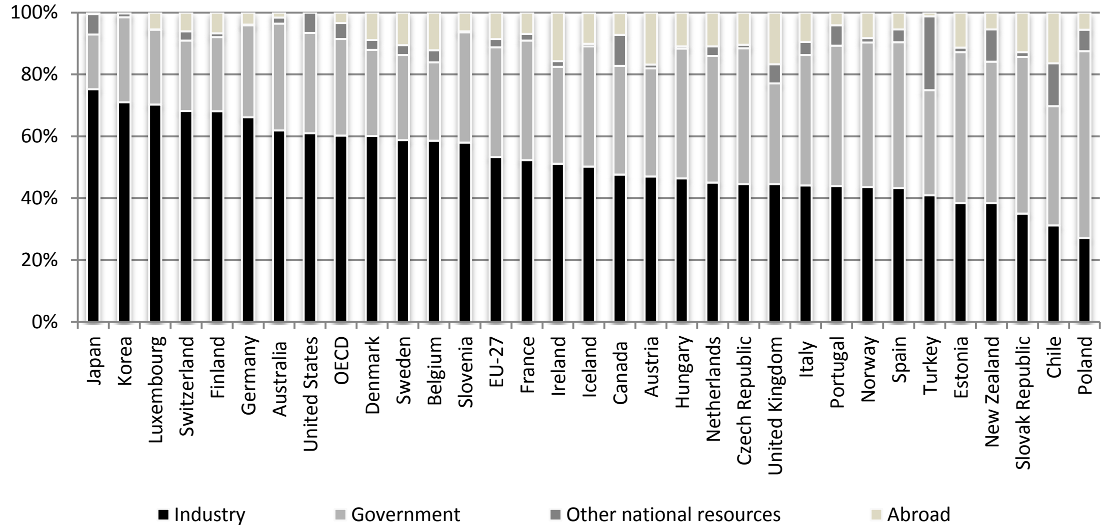

Figure 5. Financing of the Gross domestic expenditure on R&D (GERD) by institutional sectors, 2009[6,7]

Each country has their 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, Figure 6 displays a two-dimensional view of this set of key indicators obtained by using a statistical method called Factor Analysis[8]. 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). 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.

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[6] OECD Main Science and Technology Indicators, 2012.
[7] Australia, Iceland and Switzerland, data for 2008.
[8] 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. 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 coeficients

Indicator[9]	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[10]	0.114	**0.983**

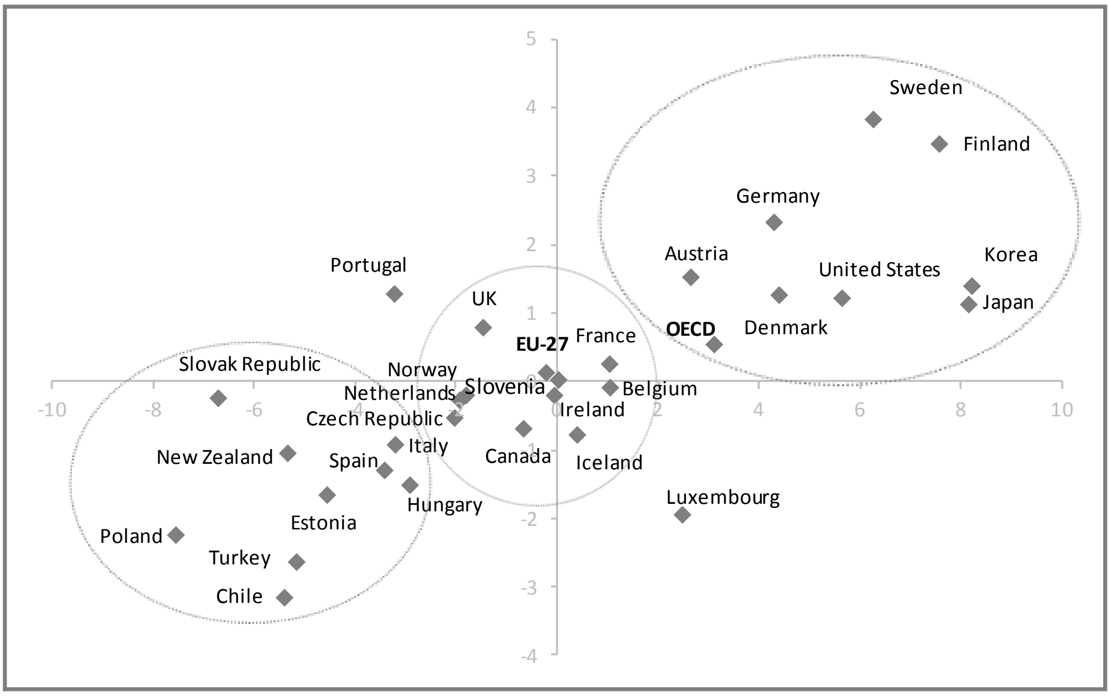

Figure 6.Two-dimensional view of R&D indicators for OECD countries in 2009.

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.

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.

[9] 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.
[10] New doctorate graduates (ISCED6) per 1000 population aged 25-34 in 2009. Source: Eurostat.

3. PhD graduates, high qualified employment and outputs of research and innovation.

In the absence of consolidated data on doctorate holders employed in the business sector, employment in knowledge-intensive activities is often identified as a measurable indicator of driving innovation[11]. Our approach, by using econometric models, is to 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.

Table2. R&D indicators

Indicator[12]	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.

[11] This indicator is only available for European countries. Source: Eurostat.
[12] 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*. We have tested a number of models and Table 4 reports the ones 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 Figure 6 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).

The estimation of Model 3 presents 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 1, 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. Consistent with our expectations, one 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 someone smaller than the effect of the international scientific co-publications on employment. Model 4 and Model 5 show 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.

The principal **conclusion** of this Section is 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 this 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.

4. Government funding for business expenditure on R&D, PhD graduates and innovative firms.

The empirical evidence highlighted the importance of business expenditure on R&D for PhD employment in the private sector and, although it is highly correlated with the private sector funding, governments can choose among various tools to leverage the investment of the private sector on R&D. They can offer firms direct support via grants or they can use fiscal incentives. Direct government funding of BERD (*Business Expenditure on R&D*) is given through grants, loans and procurements that government give to private firms. By contrast, in other countries a substantial part of government support to business R&D is indirect through R&D tax incentives (R&D tax credits, R&D allowances, reduction in R&D workers' wage taxes and social security and accelerated depreciation of R&D capital). Figure 8 shows an international comparison of public support to R&D for OECD countries in 2008.

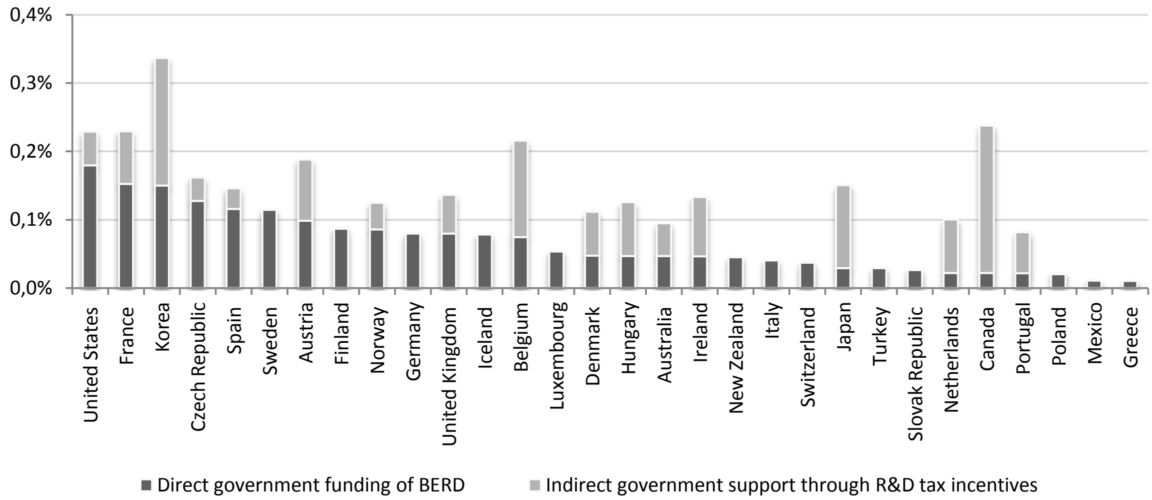

Figure 7. Government funding of R&D[13] as a percentage of GDP, 2008[14,15].

Countries as the United States, France and Spain rely more on direct support, while Canada, Japan and Korea mostly use indirect support to foster industrial R&D. The optimal balance of direct and indirect R&D support depends on each country. For instance, tax credits mostly encourage short-term applied research, while direct subsidies affect more long-term research. Although most people believe that government R&D activities contribute to innovation and productivity, many economists and policies have grown frustrated with the paucity of

[13] Direct government funding of R&D is the amount of business R&D funded by the government as reported by firms. Is the sum of different components (contracts, loans, grants/subsidies) with different impacts on the cost of performing R&D.

[14] Source: OCDE R&D Tax incentives questionnaire, 2010 and OCDE Main Science and Technology Indicators Database.

[15] Czech Republic, Spain, Sweden, Austria,Finland, Germany, Belgium, Luxembourg, Hungary, Ireland, New Zealand, Italy, Japan, Turkey, Netherlands, Portugal, Poland and Mexico, 2007. Australia and Greece, 2006.

systematic statistical evidence documenting a direct contribution from public R&D (David, P.A. et al., 2000). Note that whereas Spain is between the top five countries that promotes higher direct R&D support, this policy didn´t have a significant impact on the business expenditure on R&D (Spain is ranked in the bottom ten positions from Figure 1). One possible reason is that the direct government funding target specific projects with high potential social returns which would not have a substantial direct impact on the firm's own productivity or performance innovation.

4.1. Government funding for business expenditure on R&D

In this section we examine the effect of government funding for private R&D on business expenditure on R&D**.** Table 5 shows the different measures of government funding and Table 6 presents the estimated econometric models.

Table 5. Government funding indicators[16]

Indicator[17]	Definition
Direct government funding of R&D as percentage of GDP	Direct government funding of R&D is the amount of business R&D funded by the government as reported by firms. Is the sum of different components (contracts, loans, grants/subsidies) with different impacts on the cost of performing R&D.
Indirect government funding of R&D as percentage of GDP	Indirect government support for firms through R&D tax incentives (R&D tax credits, R&D allowances, reduction in R&D workers' wage taxes and social security and accelerated depreciation of R&D capital).
Tax subsidies for SMEs	Tax subsidies for Small and Medium Enterprises for every dollar invested in R&D
Tax subsidies for Large Enterprises	Tax subsidies for Large Enterprises for every dollar invested in R&D

Table 6. Analysis of the indicators that influence *Business expenditure on R&D (BERD)*

Dependent variable: *Business expenditure on R&D (BERD)*						
	Model1	**Model2**	**Model3**	**Model4**	**Model5**	**Model6**
	Coefficients					
Intercept	-0.165	-0.308**	-0.250	-0.249*	-0.235	-0.348
New doctorate graduates	0.782*	0.738*	0.734*	0.810*	0.807*	0.842*
Direct Government Funding		2.479	3.267*			
Indirect Government Funding		1.269		1.982**		
Tax subsidies for SMEs					0.309	
Tax subsidies for Large Enterprises						0.761
$\overline{R}^2$	0.83	0.84	0.87	0.86	0.82	0.83

*Significant at 5% level

Model 1 in Table 6 suggests that new doctorate graduates, as a measure of the supply of highly qualified human capital, explain 83% of the variability of the business expenditure on R&D.

[16] OECD, based on OECD R&D tax incentives questionnaire, January 2010; and OECD Main Science and Technology Indicators Database, March 2010.
[17] High-technology exports are not included in the analysis due it has not significant correlations with the other variables (see Table 3).

Moreover, increasing by one unit the rate of new doctorate graduates implies that the business expenditure on R&D will increase 0.78% of GDP. We find evidence that investing in new doctorate graduates increase the knowledge-intensity of the labour force in the private sector and in consequence, all the innovative outputs of firm's activities. From Models 3 and 4 we can observe that Direct government funding of business R&D and Indirect government support through R&D tax incentives have a strong and positive effect on the business expenditure on R&D (Models 3 and 4). However, the subsidies to SMEs and Large Enterprises do not have a statistically significant impact (Models 5 and 6).

The next section provides an international comparison to capture the extent that firms innovate as a consequence of the public policies for R&D, the investment in R&D and highly skilled human resources represented by doctoral graduates, for European countries in 2009.

4.2. Government funding, investment in R&D, PhD graduates and innovate SMEs

Innovation is a critical organizational outcome for its potential to generate competitive advantage. While the contribution of knowledge workers to the generation of innovation is widely recognized, little is known about how organizational incentive mechanisms stimulate or inhibit these worker's behaviors that promote innovation. We pay special attention to the case of SME. Typically, in some countries SME account for a large share of the labour force. In Spain these figure rises up to 80%. However it is difficult for this type of enterprises to find incentives strong enough to invest in R&D.

Innovation performance is a broad concept that can basically be classified into product or process innovation and marketing or organizational innovations[18]. Figures 8 and 9 show that the percentage of SMEs who introduced a new product or a new process to one of their markets and the percentage of SMEs who introduced a new marketing innovation or organizational innovation to one of their markets[19] in 2009, respectively.

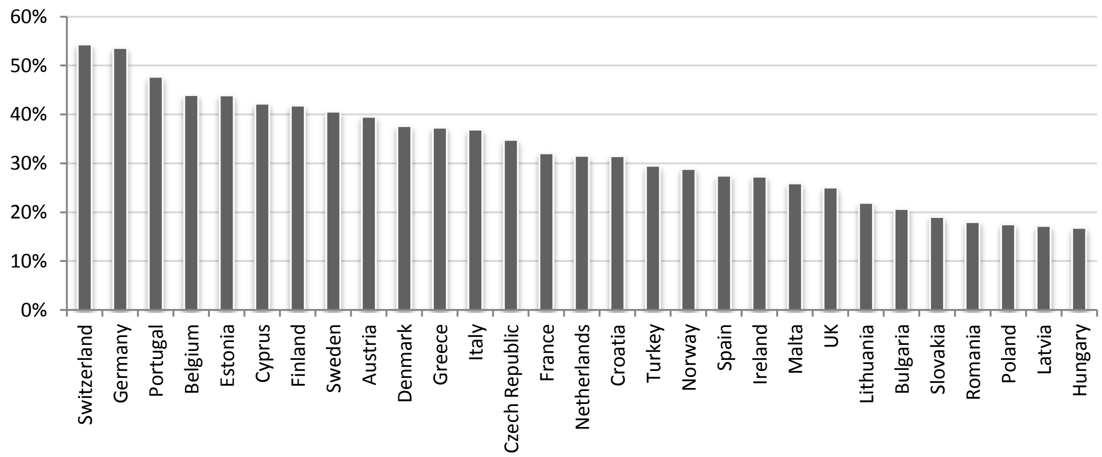

Figure 8. SMEs introducing product or process innovations as percentage of SMEs, 2009[20]

[18] The Oslo Manual (OECD, 2005) introduced two new types of innovation, namely, *organizational innovation*, related to improvements in the working place, labour practices or external relations, and *innovation in the methods of marketing* (design, pricing, brands, logos, etc).
[19] These indicators are limited to SMEs because almost all large firms innovate and because countries with an industrial structure weighted towards larger firms tend to do better. Eurostat.
[20] Innovation Union Scoreboard, 2011. Eurostat

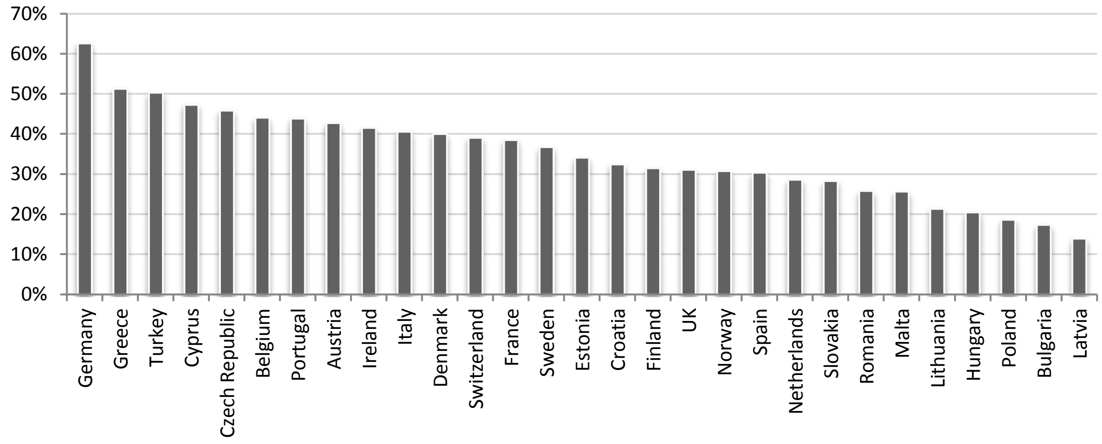

Figure 9. SMEs introducing marketing or organizational innovations as percentage of SMEs, 2009[21]

We can observe that SMEs in Switzerland and Germany share the higher level of innovation activities, more than 50%, reflecting higher shares of technological innovators. Moreover, Germany is also the country where more than 60% of the firms (SMEs) are innovate through other non-technological forms of innovation, i.e., with marketing and/or organizational innovations.

Next, our interest is focused on exploring whether government funding for R&D stimulate the firm's behavior that promote innovation for European countries in 2009. For this task, we explore the relationships between government funding, expenditure on R&D, highly qualified labour force, research and innovation outputs and firm's innovative activities. By using Factor Analysis we found out, for the analyzed countries, that (1) government funding for private R&D activities is not linked to innovation activities of SMEs and (2) doctorate graduates is one of the strategic players in the good performance of European innovation leaders.

The estimated factor's coefficients are shown in Table 8. These three factors explain 86% of the variability of the data set. The evidence reveals that Factor 1 captures the expenditure on R&D, highly qualified labour force, research linkages and economic effects. Factor 2 captures the government funding for private R&D activities and Factor 3 captures the effects of firm's innovation activities on SMEs.

Figures 10 to 12 despites the two-dimensional views of this set of R&D indicators obtained by using Factor Analysis. Figure 10 shows the first and second factor. The horizontal axis represents the first factor and the vertical axis the second factor. Similarly, Figure 11 shows the first and third factor and Figure 12 the second and third factor.

[21] Innovation Union Scoreboard, 2011. Eurostat

Table 8. Factor's coefficients

Indicator	Factor1	Factor2	Factor3
New doctorate graduates	**0,621**	-0,363	0,405
Employment in knowlodge intensive activities	**0,879**	-0,112	0,039
Public-private co-publications	**0,939**	-0,118	0,040
Internatinal co-publications	**0,936**	-0,027	0,068
Public expenditure on R&D	**0,820**	0,134	0,289
Business expenditure on R&D	**0,841**	-0,092	0,424
PCT patent applications	**0,908**	-0,190	0,269
Licence and Patent revenues from abroad	**0,839**	-0,177	-0,119
Government support for BERD (direct and indirect)	0,218	**0,888**	0,062
Tax subsidies for SMEs	-0,233	**0,929**	-0,102
Tax subsidies for large Enterprises	-0,328	**0,909**	0,018
SMEs introducing product or process innovations	0,435	-0,098	**0,841**
SMEs introducing marketing or organizational innovations	-0,064	0,082	**0,946**

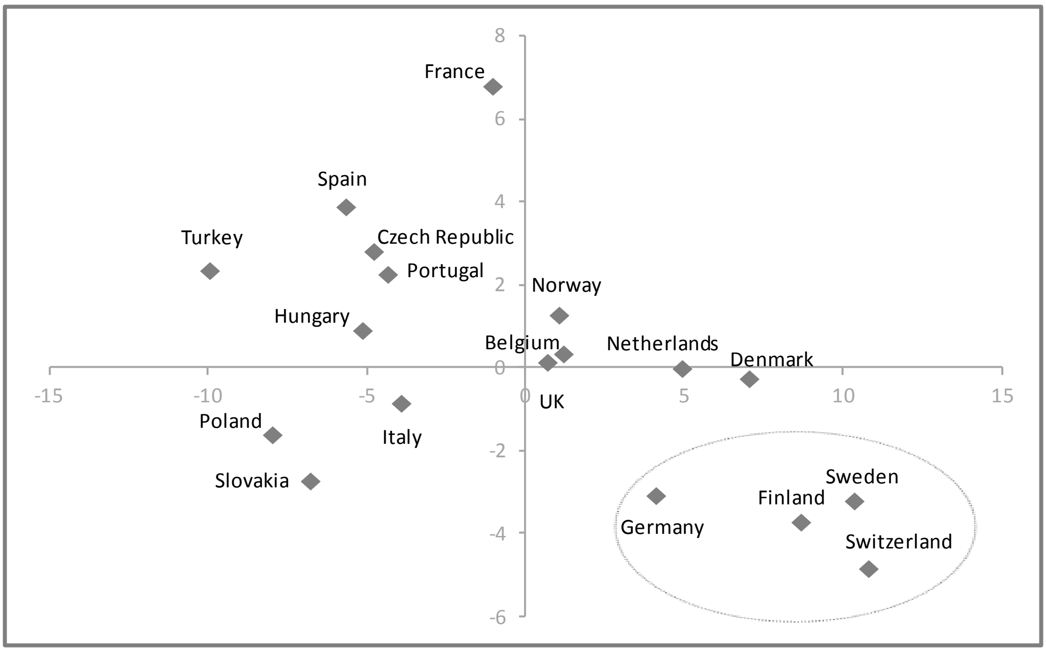

Figure 10.Two-dimensional view (factor 1 is the horizontal axis and factor2 the vertical axis) of innovation performance for European countries in 2009.

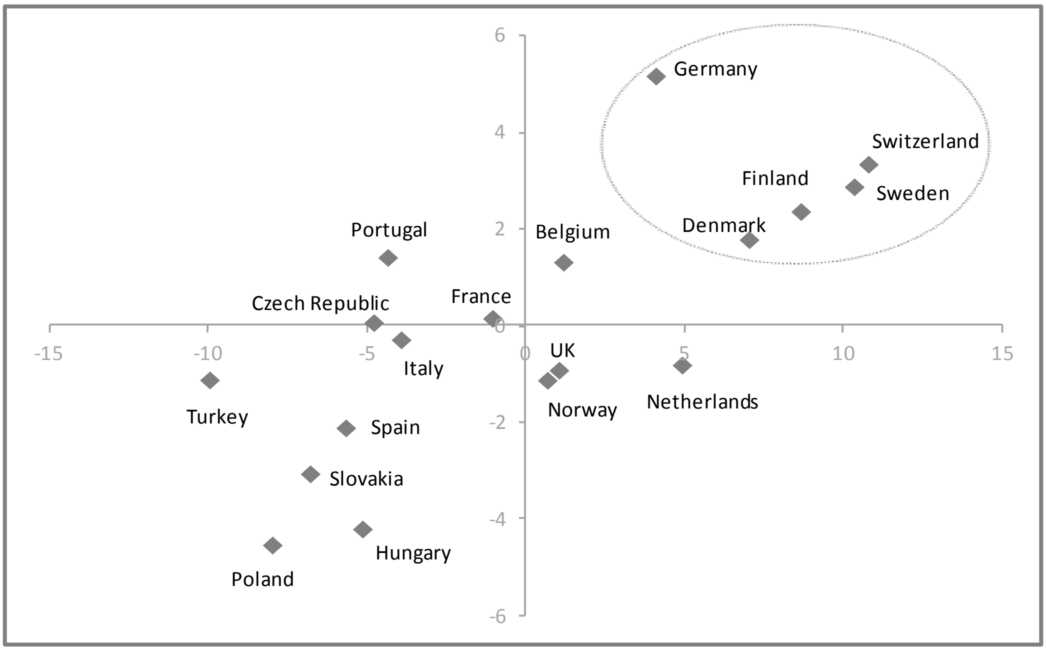

Figure 11.Two-dimensional view (factor 1 is the horizontal axis and factor3 the vertical axis) of innovation performance for European countries in 2009.

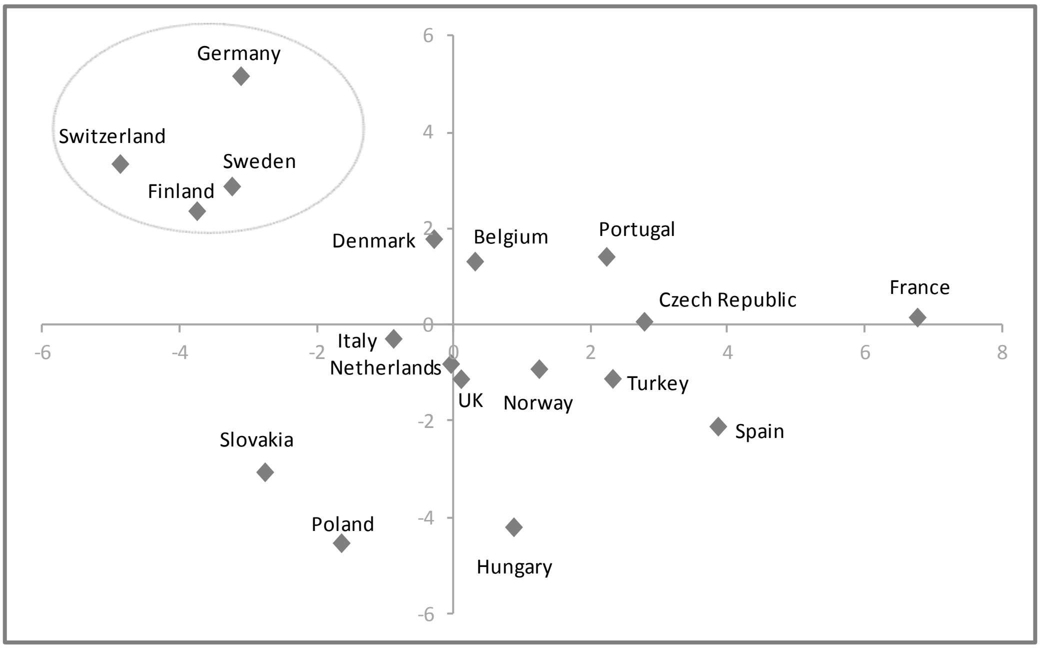

Figure 12.Two-dimensional view (factor 2 is the horizontal axis and factor3 the vertical axis) of innovation performance for European countries in 2009

Notice that the overall good performance of the European innovation leaders reflects a balanced national research and innovation system. It means that the innovation leaders as well as the innovation followers have a good performance across all the innovation dimensions. Note than from Figure 10 the innovative leaders, Denmark, Germany, Finland, Sweden and Switzerland have negative scores on Factor 2, i.e., these countries do not need government support to BERD neither subsidies to enterprises.

4. Conclusions

In this paper by using econometrics/statistical techniques we searched the main drivers of research and innovation along OECD countries and one of them is the supply of new PhD graduates. We identify the factors most relevant to boost the employment of the PhD holders, especially in the business sector. We also analyze the influence of government funding for private R&D and firm's innovation. One key finding contrary to a common belief is that R&D expenditures in the public sector are not sufficient and efficient by themselves to boost the innovation performance of the countries. Universities and public research centers are the natural recipients of these funds, but the migration process of their outputs of research and technology from these *temples of knowledge* to the society requires the simultaneous R&D expenditure in the business sector. The success of the R&D funding offered is based on the government's ability to design it and on the use of firms' expected profit. As discusses in Section 1, the more research-intensive countries share a higher expenditure on private R&D than in public R&D. Consequently, their employment of PhD in the private sector boosted. We learned from our Model 3 in Table 4 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.***

Whilst governments and universities provide support to increase the production of new doctorate holders, government funding for private R&D has not, in general, the expected economic effect on the innovative activity of firms.

It is clear that innovation always entails a certain amount of risk, however, successful innovation is to a large extent an issue of identifying and controlling that risk. In this context doctoral graduates are key players for research and innovation, as well as to manage successfully that risk, so there is a crucial link between employability of PhD holders and opportunities for innovation. While the most innovative countries improve their performance, others have shown a lack of progress. In order to boost their innovation performance, countries need to concentrate their efforts in the employability of doctorate holders, specifically, in the private sector. Looking at innovation leaders in Europe, with Germany, Finland, Sweden and Switzerland at the top, we found out that their graduation rate of new doctorates is higher than 2.6, while the average graduation rate in Europe is 1.5.

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