The importance of R&D and Patents for National Development

Abstract

The level of R&D spending of a country increases the innovativeness of its firms and, in consequence, should collaborate with its economic growth. However, very few empirical studies investigate this phenomenon comparing countries from all over the globe, dismembering the sources of R&D spending, and trying to identify the role of innovation performance as a mediator in the relationship between R&D spending and national development. This was the main goal of this paper. Using a panel data of 35 countries from four continents (with the exception of Africa) and fifteen years (from 1999 to 2013), we could identify that R&D spending from firms and universities help to improve national development (measured by GDP per capita, GNI per capita and HDI) if they succeed in increasing the level of patent applications nationally.

Keywords: R&D spending; Innovation; Patent applications; National Development

Introduction

The academy has been studying extensively the relationship between the introduction of innovation by firms and their financial performance. Most scholars agree that this relationship should be positive (Du et al., 2014; Yamakawa et al., 2011) for several reasons. Considering the four types of innovation proposed by the Oslo Manual (OECD, 2005), product innovation allows the firms to fulfil gaps on the demand (Galindo & Méndez, 2014) by the launch of new products with better costs or quality (Ateljević & Trivić, 2016); process innovations promote cost reduction and increases in productivity by improvements in the production process (Moutinho et al., 2015; Terjesen & Patel, 2017); organizational innovation brings a higher resilience against the external environment by strategic renewal (Hamel & Välikangas, 2004); and marketing innovation increases the competitiveness of a brand (Gupta et al., 2016). However, there are research lines that propose that the influence is inverse, in which a positive financial performance increases the innovativeness (Ryu & Lee, 2018), as unsuccessful firms will invest their resources on their basic operations and not focus on innovation. Some empirical studies, in their turn, did not find any relationship between both constructs (e.g., Paula & Silva, 2018).

It is generally recognized that it is more difficult to understand an individual behavior than the collective behavior. With such in mind, and considering that the reasons mentioned above consistently justifies that innovation should help to improve firm performance, we may conclude that the collectiveness of firms in a country should have their performances boosted by the national innovativeness level and that it would help to promote economic development and well-being for the population. Some facts reinforce this supposition. The 16 leaders of the Global Innovation Index - GII (Cornell University et al., 2018), for example, are among the 30 countries with higher projected 2019 nominal GDP per capita (Statistics Times, 2019). Despite this apparent correlation, causality is not certain as a richer country may become more innovative as a result of increased investments incentivized by its wealth (Orihata, 2001). Besides, a group of successful innovative firms in the same region may not automatically cause regional development. More automated new entrants, for instance, may be substituting old incumbents and destroying jobs. Thereupon, more studies relating regional and national innovation and development are needed. The academic literature extensively explored the relationship between R&D, innovation and performance at the firm level while studies at a regional or national level are scarcer. Specifically concerning R&D investments, studies that investigate the effectiveness of national investments on R&D conducted by different stakeholders are rare. To tackle the identified literature gap, this study intends to investigate the effect of innovation and investments in R&D on the growth of national economies, which is reflected by the proposed research question: *How the sum of investments in R&D made by diverse stakeholders (e.g., firms, government, universities and non-profit organizations) and other innovation activities (specially patent applications) in the national level influence a country´s development?*

To answer the research question, this paper formulated five hypotheses regarding the influence of national investments in R&D by the four stakeholders cited, patent application and national development. National development was measured by the gross domestic product (GDP) per capita, gross national income (GNI) per capita and human-development index (HDI). We used data from 35 countries from the OECD Statistics database (OECD, 2018), covering the years of 1999 to 2013 and the estimation was conducted using panel regression analysis (robust least squares).

We structure the paper as follows: first, the literature review presents studies related to the subject and the hypotheses are formulated; the next section is method, containing a description of the data and of sample selection method, the variables and model proposed, and of the statistical method used. Next, results are described, and a conclusion is presented.

Literature Review

We argued previously that studies focusing on the effect of innovation on economic performance of regions and countries are scarcer than the ones focusing on firm performance. Although it is true, several authors studied this relationship on the country level, concluding that innovation introduced by local firms is an important factor to promote regional development and economic growth (e.g., Ahlstrom, 2010; Kiselitsa et al., 2017) Heidenreich (2009), for instance, concluded in his study that innovation promotes economic growth in several regions from Europe. Kiselisa et al. (2017) found similar results in Russia. Paula and Silva (2019), studying the effect of product and process innovation in the economic development of Brazilian provinces, found that process innovation was positively related to economic growth in the medium and long term. Regarding these findings, Trinh (2017) argued that the set of innovations introduced by firms in a region shifts up the curve of capital accumulation versus GDP growth, allowing regions with stronger development of high technological innovation to have a superior GDP growth than others with the same level of capital accumulation level but lower innovative rate. This phenomenon is allowed because innovation usually generates new businesses, jobs and sources of tax collection (Ahlstrom, 2010). Although innovative firms may drop the less innovative ones from the market (Christensen, 2013), this trade off should be positive, because some of the old incumbents may not fail, but become more innovative and expand, and this movement may increase the market share, production efficiency and economic growth for a country (Shefer & Frankel, 2005). The previous arguments reinforce a positive relationship between innovation and regional development.

If firms' innovativeness is important for regional and national development, it is necessary to understand how to improve their innovation performance. The latter is improved by an appropriate equilibrium between different sources of R&D investment (internally made by firms and external investments), highly educated employees and an active collaboration network, including the participation of the government (Paula & Silva, 2017). Therefore, we may conclude that aggregated investments in R&D by different stakeholders should be complimentary in improving innovation performance of firms in general and, in consequence, regional and national growth. Innovation performance is measured in different ways in the academy. Several authors use number of innovations introduced (e.g., Tomlinson, 2010), others use measures indicating the degree of innovativeness (e.g., Ozer & Zhang, 2015), while others prefer scales measuring innovation impacts on revenues or on reducing costs (e.g., Paula & Silva, 2017; 2018). Number of patents is another proxy commonly used (e.g., Hagedoorn & Wang, 2012; Schilling, 2015), although it is not perfect as it is more common in product innovation; some firms opt for not to patenting because of the risk of copying (Hall, 2014); and are more appropriate for specific sectors, such as the science-based ones (Pavitt, 1984). However, it is the most precise and easy to get innovation performance proxy at the national level as countries' patents are registered according to a formal process in national patent offices, such as the United States Patent and Trademark Office (USPTO, 2019) and the European Patent Office (EPO, 2019). Thereby, it is appropriate for studying the relationship among investments in R&D, innovation performance and national economic growth and development. Considering what was discussed up to here, we proposed the following hypotheses:

H1a: The national level of investments in R&D made by firms positively influences the level of patent applications in a country;

H1b: The national level of investments in R&D made by higher-education institutes (including universities) positively influences the level of patent applications in a country;

H1c: The national level of investments in R&D made directly by the Government positively influences the level of patent applications in a country;

H1d: The national level of investments in R&D made by private non-profit organizations positively influences the level of patent applications in a country;

H2: The national level of investments in R&D (by firms, higher-education institutions, the Government and private non-profit organizations) has an indirect influence on national development, mediated by the level of patent applications in the country.

Method

In order to test the hypotheses, we collected data from a sample of 35 countries from the statistics database of the Organization for Economic Co-operation and Development (OECD) (OECD, 2018) in order to conduct a panel regression analysis. This method was chosen as it consists in a longitudinal model that more appropriate to find causal relationships. The data covered the years from 1999 to 2013 (a total of 15 periods). The countries in our sample were: Australia, Austria, Belgium, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, China, and Russia. Considering the 35 countries and the 15 periods, the total sample was formed by 525 cases.

The proposed model runs in two stages. The first stage, which tests hypotheses 1a, 1b, 1c and 1d, has the variable *patent_population(y)* as the dependent variable, corresponding to the average of patents applied in the country divided by the population in the considered year. The dependent variables in this first stage are: i) *%_r&d_enterprise* – the total spending in r&d by firms in the country divided by the gross domestic product (GDP); i) *%_r&d_government* – the total spending in r&d by the government divided the GDP; iii) *%_r&d_higher_education* – the total of spending r&d by higher education institutes divided the GDP; iv) i) *%_r&d_private_non_profit_orgs* – the total spending in r&d by the private non-profit organizations divided the GDP; v) *%_full_time_researchers* – control variable representing the total of full-time researchers divided by the population; vi) *population* – control variable which counts the total population of the country (divided by 1.000); vii) *Asia* – dummy variable that is 1(one) it the country is in Asia and 0(zero) if it is not; viii) *Europe* – dummy variable that is 1(one) it the country is in Europe and 0(zero) if it is not; ix) *Oceania* – dummy variable that is 1(one) it the country is in Oceania and 0(zero) if it is not; x) *LA* – dummy variable that is 1(one) it the country is in Latin America and 0(zero) if it is not (all four dummy variables being 0, the country is in North America); and xi) *patent_population (year-1)* – the total patents by population of the previous year. Equation (I) represents the first stage:

$$\text{(I)}\quad \textit{patent\_population(y)} = \beta a0 + \beta a1 * \textit{\%\_r\&d\_enterprise} + \beta a2 * \textit{\%\_r\&d\_government} + \beta a3 * \textit{\%\_r\&d\_higher\_education} + \beta a4 * \textit{\%\_r\&d\_private\_non\_profit\_orgs} + \beta a5 * \textit{\%\_full\_time\_researchers} + \beta a6 * \textit{population} + \beta a7 * \textit{Asia} + \beta a8 * \textit{Europe} + \beta a8 * \text{Oceania} + \beta a9 * \text{LA} + \beta a10 * \textit{patent\_population(y-1)} + \varepsilon$$

The second stage, on its turn, intends to verify the influence of patents on country performance / development, which was proposed by hypothesis 2. To achieve this goal, we run three different regressions for each of the following dependent variable: i) *GNI_PC* – gross national income per capita; ii) *GDP_PC* – gross domestic product per capita; and iii) *HDI* – human development index. As independent variables, the model presents: iv) *patents_regression* – the result of the calculation of *patents_population* by equation I in the first stage. This is more appropriate than taking *patents_population* as the former method drops error variance; v) *%_full_time_researchers*; vi) *population*; vii) *Asia;* viii) *Europe*; ix) *Oceania*; x) *LA*; and xi) *dependent variable (year-1)* – the dependent variable of the previous year. Equation (II) represents the second stage:

(II) $[GNI\_PC;\ GDP\_PC;\ HDI](y) = \beta a0 + \beta a1 * patents\_regression + \beta a2 * \%\_full\_time\_researchers + \beta a3 * population + \beta a4 * \mathrm{Asia} + \beta a5 * \mathrm{Europe} + \beta a7 * \mathrm{Oceania} + \beta a8 * \mathrm{LA} + \beta a9 * [GNI\_PC;\ GDP\_PC;\ HDI]\ (y\text{-}1) + \varepsilon$

We chose robust least-squares to run these panel regressions. This choice was justified because it is more robust for normality deviations and heteroscedasticity (Moutinho et al., 2015), which were a problem in the data. From these cases, the software used to run the robust least squares (RLS) analysis (eViews) kept 268 cases, after the exclusion of the ones (country/year) with missing data.

Results

Table 1 shows the average of the variables of the model in the period of 1999 to 2013 (some data in some years are missing. It that happened, we did not consider it on the average). The table also shows the average for each continent. From the data, we perceived that North America (represented only by the US) has most patent applications in the proportion of its population, followed by Asia and Europe. The US also presents more investments on R&D by enterprises and by private non-profit organizations (followed in both cases by Asia), and by the Government (followed by Oceania). Regarding higher education institutes (such as universities), Oceania and Europe are the leaders. We also could observe that the proportion of full-time researchers on the population is higher in Europe, followed by Asia.

[TABLE 1]

The results found by the RLS analysis supported most of the hypothesis. Table 2 shows the results of the first stage of the model. According to it, hypothesis H1a (positive effect of firms' internal R&D spending on patent applications) and H1c (positive effect of higher education institutes' R&D spending on patent applications) were supported, which confirmed the vocation of firms and universities to develop basic (both) and applied research (mainly firms) that turn into patented technologies. On the other hand, the effect of R&D investments from the Government and from private non-profit organizations did not present a positive effect (affirmative supported by the rejection of H1b and H1d).

The second step of the analysis supported H2 (see Table 3). The three country development indicators (GNI per capita, GDP per capita and HDI) were positively influenced by the ratio of patent applications and population. The direct influence of patents on country development, therefore, indicated an indirect positive effect of R&D from firms and from higher education institutions on country development, which was mediated by patent application.

[TABLE 2]

[TABLE 3]

Discussion and Final Remarks

This article studied the influence of national spending in R&D from diverse sources in national development mediated by the level of patent application. This subject is important as the different stakeholders have limited resources and the strategic choice of investing in R&D represents a deviation of focus from other areas. Our findings supported the existence of a positive influence of national investments in R&D made by firms and universities on national development mediated by patent application. The same was not observed with investments made directly by the Government or by private non-profit organizations. The findings indicated that only investments in R&D that turn into an increase of the innovation performance helps to boost national economic growth. Patent applications, altough do not represent all types of innovations, is important an indicator of innovation performance and, in consequence, have a significant positive influence on indicators such as GDP per capita, GNI per capita and HDI. Possibly, R&D from the other two sources (Government and non-profit organizations) are important inputs for non-patented innovation, which were not covered by our data. Another interesting finding was that the influence of those types of R&D spending were found not only when economic measures of national development were used (such as GDP and GNI), but also when HDI was considered, being it from different nature, as it is an index that balances diverse measures of economic and social development and is more precise in measuring the population's well-being.

These results have a considerable importance to practice. The importance of governmental policies to foment innovation is widely recognized. The results of this study are very interesting for national governments as it may help to better orientate them on which types of innovation policies to focus in order to foment national development more effectively. Our analyses indicated that tax exemptions for R&D conducted by firms and investments in applied research conducted by universities may be more effective than directly financing R&D

activities through governmental research institutes or supporting non-profit organizations, as the formers sources of R&D spending have stronger correlations with patented innovation rates and national development indicators. The Government have an important role as the orchestrator of the national innovation system, especially in developing economies. Therefore, it is important to better direct the scarce resources from the taxpayers to more effective innovation policies in order to foment national development, benefiting the maximum number of people.

This study is not without limitations. The first one we mention is that we could not consider other proxies than patent applications to represent innovation performance. The usage of other proxies could show significant positive influence from R&D spending from other stakeholders. Another limitation is that not all countries in the sample were considered because of the missing values in some years, which obligated us to drop the whole country from the database. Even with these limitations, this study brought interesting theoretical and practical implications as it identified the importance that investments in R&D from specific sources at the national level that effectively result in innovativeness have a positive consequence not only on national development considering economic measures, but also considering broader proxies such as the HDI.

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Table 1: Characteristics of the sample (avg. 1999 to 2013)

Variable / Country	patents_population	%_R&D_enterprise	%_r&d_government	%_r&d_higher_education	%_r&d_private_non_profit_orgs	%_full_time_researchers	population (x1000)
Asia	**0.108**	**0.001900%**	**0.000341%**	**0.000301%**	**0.000062%**	**0.295914%**	**499,860**
China	0.005	0.000768%	0.000328%	0.000117%	-	0.077690%	1,323,659
Japan	0.197	0.002571%	0.000308%	0.000464%	0.000080%	0.514137%	127,457
Korea	0.121	0.002360%	0.000385%	0.000321%	0.000044%	-	48,463
Europe	**0.099**	**0.001122%**	**0.000236%**	**0.000436%**	**0.000023%**	**0.322674%**	**25,309**
Austria	0.132	0.001794%	0.000137%	0.000667%	0.000010%	0.385229%	8,218
Belgium	0.094	0.001541%	0.000169%	0.000477%	0.000023%	0.321825%	10,633
Czech Republic	0.014	0.000827%	0.000319%	0.000270%	0.000006%	0.212780%	10,352
Denmark	0.199	0.002070%	0.000204%	0.000776%	0.000019%	0.564242%	5,447
Estonia	0.019	0.000577%	0.000173%	0.000563%	0.000023%	0.268919%	1,353
Finland	0.278	0.002611%	0.000359%	0.000723%	0.000024%	0.681209%	5,286
France	0.099	0.001563%	0.000398%	0.000481%	0.000033%	0.346633%	61,395
Germany	0.194	0.001920%	0.000394%	0.000474%	-	0.361710%	81,821
Greece	-	0.000204%	0.000148%	0.000276%	0.000006%	0.152370%	11,051
Hungary	0.020	0.000586%	0.000275%	0.000255%	-	0.180316%	10,072
Iceland	0.113	0.001361%	0.000558%	0.000599%	0.000063%	0.602179%	303
Ireland	0.075	0.000983%	0.000091%	0.000352%	-	0.273913%	4,218
Italy	0.046	0.000650%	0.000206%	0.000387%	0.000034%	0.140910%	58,377
Latvia	-	0.000212%	0.000130%	0.000245%	0.000000%	0.149167%	2,236
Luxembourg	0.103	0.001095%	0.000266%	0.000112%	-	0.468189%	476
Netherlands	0.197	0.001065%	0.000260%	0.000668%	0.000020%	0.312177%	16,315
Norway	0.133	0.000973%	0.000280%	0.000536%	-	0.505725%	4,721
Poland	0.005	0.000256%	0.000252%	0.000241%	0.000002%	0.152392%	38,289
Portugal	0.008	0.000484%	0.000149%	0.000422%	0.000109%	0.250585%	10,449
Russia	0.005	0.000954%	0.000384%	0.000088%	0.000003%	0.325818%	144,307
Slovak Republic	0.007	0.000370%	0.000195%	0.000136%	0.000001%	0.206550%	5,386
Slovenia	0.049	0.001177%	0.000370%	0.000251%	0.000007%	0.286154%	2,018
Spain	0.028	0.000666%	0.000218%	0.000358%	0.000004%	0.237887%	43,948
Sweden	0.294	0.002685%	0.000149%	0.000862%	0.000008%	0.536533%	9,130
Switzerland	0.264	0.002245%	0.000037%	0.000748%	0.000058%	0.371349%	7,526
Turkey	0.004	0.000281%	0.000073%	0.000376%	-	0.067415%	69,538
United Kingdom	0.097	0.001144%	0.000180%	0.000440%	0.000035%	0.350023%	60,488
Latin America	**0.002**	**0.000143%**	**0.000089%**	**0.000139%**	**0.000043%**	**0.022642%**	**101,332**
Chile	0.003	0.000119%	0.000023%	0.000135%	0.000074%	0.035024%	16,380
Mexico	0.002	0.000168%	0.000156%	0.000144%	0.000012%	0.032900%	107,739
North America	**0.150**	**0.002274%**	**0.000373%**	**0.000390%**	**0.000121%**	**-**	**298,182**
United States	0.150	0.002274%	0.000373%	0.000390%	0.000121%	-	298,182
Oceania	**0.084**	**0.000828%**	**0.000349%**	**0.000495%**	**0.000059%**	**0.190336%**	**12,460**
Australia	0.088	0.001148%	0.000305%	0.000569%	0.000059%	0.380672%	20,764
New Zealand	0.081	0.000508%	0.000393%	0.000420%	-	0.000000%	4,156

Table 2: Robust least squares (*patents_population*)

	Coeff.	S.E.
Predictors		
%_r&d_enterprise	0.027***	0.007
%_r&d_government	0.000	0.004
%_r&d_higher_education	0.021***	0.006
%_r&d_private_non_profit_orgs	-0.004	0.004
%_full_time_researchers	-0.021***	0.004
population	0.007	0.021
Asia	0.181***	0.018
Europe	0.022***	0.006
Oceania	0.052**	0.026
LA	0.030	0.020
patent_population (y-1)	0.985***	0.007
Model Fit		
R2 / Adj. R2	0.705	
Rw / Adj. Rw	0.997	
Prob (Rn2 stat.)	0.000	

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$

Table 3: Robust least squares (Country development variables)

Dependent variable	*GNI_PC*		*GDP_PC*		*HDI*	
	Coeff.	S.E.	Coeff.	S.E.	Coeff.	S.E.
Predictors						
patents_regression	0.031***	0.009	0.021***	0.008	0.020***	0.007
%_full_time_researchers	-0.012*	0.007	-0.011*	0.006	-0.013**	0.006
population	-0.032	0.027	-0.036	0.023	-0.155***	0.032
Asia	0.086***	0.022	0.076***	0.019	0.107***	0.018
Europe	0.075***	0.009	0.068***	0.008	0.035***	0.009
Oceania	0.074	0.051	0.068	0.044	0.046	0.039
LA	0.059***	0.020	0.039**	0.017	0.010	0.016
[GNI_PC; GDP_PC; HDI] (y-1)	0.988***	0.008	0.994***	0.008	0.940***	0.007
Model Fit						
R2 / Adj. R2	0.844	0.837	0.832	0.824	0.779	0.767
Rw / Adj. Rw	0.996	0.996	0.996	0.996	0.998	0.998
Prob (Rn2 stat.)	0.000		0.000		0.000	

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.001$