



## IS PUBLIC RESEARCH BENEFICIAL FOR INNOVATION IN EMERGING AND DEVELOPING COUNTRIES?



 Kamilia Loukil

Faculty of Economics and Management of Sfax, University of Sfax, Tunisia.  
Email: [kamilia.loukil@gmail.com](mailto:kamilia.loukil@gmail.com)



### ABSTRACT

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Public sector research is considered as the main source of codified information. It also generates a variety of other forms of economic benefits. The present study aims to examine the impact of public research on technological innovation in emerging and developing countries. For this purpose, we use data on R&D expenditures performed by the sectors of government and higher education for public research, while technological innovation is measured by US patent applications. Linear regressions are applied on data for 21 countries during the period 2005-2013. Findings show that public research increases the innovation level. Furthermore, findings suggest that the two sectors play a complementary role in promotion of technological innovation. The main conclusion of our study is that the promotion of public research is an effective instrument of innovation policy in emerging and developing countries.

#### JEL Classification:

H52; O3.

**Contribution/ Originality:** This study contributes to existing literature by examining the impact of public research on technological innovation in emerging and developing countries.

### 1. INTRODUCTION

Public research aims to encourage companies to innovate. Governments finance scientific research in their organizations in order to achieve a socially optimal level of R&D investment. The results of publicly funded research are supposed to be exploited by the business sector for the development of innovations. This is the main justification for public funding of basic research according to Arrow (1962). Public research is therefore supposed to expand the knowledge base for companies. However, governments are facing increasing pressure to justify public spending on research, and the traditional rationale for public funding of research needs to be expanded. In fact, in a context of budget constraints and increased research costs, there is growing pressure on public research to improve its contribution to innovation and meeting the needs of the public society.

Public sector research is not only a source of codified information but also generates a variety of other forms of economic benefits. A more effective legitimacy of public support for research must take into account all these forms (Salter and Martin, 2001). First, public research increases the stock of useful information. This is a codified information that is a public good accessible by companies and other potential users. Technological and scientific information from basic research can increase the efficiency of applied R&D in industry by orienting research

towards more useful questions. Second, public research offers new instrumentations and methodologies which are used by firms in their production processes or in their industrial research activities (Klevorick *et al.*, 1995). On the other hand, firms that need specific skills in R&D or other technical functions often seek well-trained researchers. Public research offers such qualified skills. In addition, it allows access to information and networks. Formal and informal participation in scientific networks is important. Indeed, it is almost impossible for companies to provide on their own all knowledge and information they use. They therefore need to identify and absorb external knowledge (Hicks, 1995). Moreover, public research allows the application of a stock of knowledge to industrial needs. It can be particularly useful for developing the ability to solve complex problems. Finally, research in academic institutions is often the source of spin-off companies where academics transfer their skills and tacit knowledge directly to the business environment.

The present paper aims to answer the following question: How does public research affect the technological innovation level in emerging and developing economies?

For that purpose, we apply multiple linear regressions on panel data relative to 21 developing and emerging countries over the period 2005-2013. Our estimated results show that public research increases the innovative activities.

The rest of the paper is organized as follows: In Section 2 we discuss empirical results relative to previous studies. In Section 3 we introduce the data and empirical methodology. In Section 4, we present and discuss our empirical findings. In Section 5, we conclude.

## 2. LITERATURE REVIEW

Several empirical works have focused on the study of the effect of public research on knowledge production in firms. For example, Jaffe (1989) explored the effect of university research on innovation using data on company patent filings, business R&D expenditures, and university research. He found a significant effect of academic research on business patents especially in the areas of medicines and medical technologies, the industries of electronics, optics and nuclear technology. In addition, university research has an indirect effect on local innovation by stimulating industrial expenditure on R&D.

Beise and Stahl (1999) examined the effect of research at polytechnic universities and federal research labs on industrial innovations in Germany. They discussed the characteristics of companies that benefit from the results of public research institutions. By questioning 2300 companies, the authors found that less than one-tenth of innovative firms introduce innovations between 1993 and 1995 that would not have been developed without public research. These new products account for approximately 5% of sales of all new products. Firms whose innovations have received public support cite universities as the most important source of knowledge. Large scientific laboratories are almost invisible, suggesting that their technological transfer to industrial firms is inefficient. Beise and Stahl's results also show that research institutions located near the firm represent an important source of knowledge.

McMillan *et al.* (2000) studied the link between public science and innovation in the US biotechnology industry. Their results indicate that the biotechnology industry is more related to public research, particularly public basic research, than the pharmaceutical industry. These results support the idea of continued public support for basic research. The authors concluded that as long as biotechnology is considered to have the potential to revolutionize not only the pharmaceutical industry but also the chemical and agricultural industries, this public funding is strategically important to the US economy.

Cohen *et al.* (2002) studied the impact of research produced by universities and public research institutes and laboratories on industrial R&D activities. They used data from a survey conducted in 1994 on R&D managers. The sample consists of R&D units located in the United States performing R&D activities in manufacturing industries. They found that public research is beneficial to industrial R&D in a limited number of industries. The

survey responses show that public research suggests new R&D projects and also contributes to the completion of existing projects.

The study by Löfsten and Lindelöf (2002) distinguished between 273 firms inside and outside the science parks in Sweden during the period 1996-1998 in order to identify whether the park offers added value for the benefit of new technological firms. The study shows some differences as regards marketing and innovation between the experiences of firms existing within the park and those located outside the park. In fact, firms located in science parks are more likely to have a relationship with the local university and their job creation rate is higher than firms located elsewhere.

Keizer *et al.* (2002) identified the factors that relate to innovation efforts. Their study aims to find out why some firms innovate and others do not. It is based on data collected through telephone interviews with SME managers in the mechanical and electrical sector in the Netherlands. Among 14 independent variables, three appear to contribute significantly to innovation efforts: the use of innovation grants, having relations with knowledge centers and the percentage of turnover invested in R&D.

Cassia *et al.* (2009) conducted an analysis on a sample of public enterprises in UK during the period 1995-2006. They explored the effects of external sources of knowledge on the growth of new firms, with a particular focus on the role of knowledge externalities and the social sciences. The results of the analysis suggest that the inputs and outputs of academic knowledge in a specific region positively influence the growth rate of entrepreneurial firms in the early stages of the life cycle. In fact, small and new firms absorb more localized knowledge in the local environment than larger firms. The authors also highlighted the additional role of social sciences compared to the natural sciences in generating the effects of knowledge externalities. They found a positive impact of this type of science on the growth of firms.

### 3. METHODOLOGY

In this section, we first describe our sample. Next, we will define the variables used and their respective measures. Then, we will advance descriptive statistics. Finally, we will present the statistical models used in this study.

#### 3.1. Sample Selection

The present study examines a sample of 21 emerging and developing countries<sup>1</sup> for the period 2005-2013.

#### 3.2. Selection of Variables and Measurement Instruments

We will present below the variables and their measures. It is necessary to specify the dependent variable as well as the independent variables of the models to be estimated.

##### 3.2.1. Dependent Variable

Patenting is often considered an appropriate proxy to the level of innovation (Griliches, 1990; Furman *et al.*, 2002; Kanwar and Evenson, 2003).

In the absence of more reliable data, we use data from the US Patent and Trademark Office (USPTO). Our measure of technological innovation is the number of patent applications filed by residents of a given country with the USPTO. Because of the time lag between the filing process and the granting of a patent [2], using data on patent applications rather than granted patents reflects the more immediate and faster innovative activity. Data on

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<sup>1</sup>In this paper, we adopt the ranking of countries according to the report of the IMF (2012) which classifies countries into two categories: "Advanced Economies" and "Emerging and Developing Economies". Countries included in our sample are: Argentina, Bulgaria, Colombia, Costa Rica, Croatia, Ecuador, Guatemala, Hungary, Latvia, Lithuania, Mexico, Pakistan, Panama, Philippines, Poland, Romania, Russia, Serbia, South Africa, Turkey, Ukraine.

patent applications are transformed by taking their natural logarithms. Therefore, the dependent variable (PAT) is defined as the logarithm of the number of patent applications filed by a country's residents with the USPTO for a given year.

As the level of international patenting is observed with a time lag, our empirical work requires a lag of 2 years between explanatory variables and the dependent variable. Therefore, data for independent variables are for the period 2005-2013, and patent applications relate to the period 2007-2015.

### 3.2.2. Independent Variables

Public research is measured by R&D expenditures performed by public sector (RDPUB). This measure is the sum of R&D expenditures performed by the government (RDG) and R&D expenditures performed by the sector of higher education (RDHE).

Data are in '000 PPP dollars, constant prices-2005. Data are transformed by taking their natural logarithms and are from UNESCO database.

Four control variables are used in the present study:

The level of economic development is measured by GDP per capita (GDP).

The human capital is measured by the secondary education level (EDUC). The metric used is the gross enrollment ratio for secondary school.

The institutional framework is measured by the Economic Freedom Index of the Economic Report (Gwartney *et al.*, 2014) taking a value between 1 and 10 (EFI).

Foreign source of knowledge is measured by foreign direct investment inflows as a percentage in GDP (FDI).

Data on GDP, EDUC and FDI are from World Bank's World Development Indicators.

Data on GDP are transformed by taking their natural logarithms.

Data on economic freedom index are from the Fraser Institute.

### 3.3. Descriptive Statistics

Table 1 provides the descriptive statistics on the number of patents as well as the explanatory variables (RDG, RDHE, RDPUB, GDP, EDUC, EFI, FDI).

Table-1. Summary statistics.

Variable	Average	Median	Standard deviation	Minimum	Maximum
PAT	134	64	185.66	1	1007
RDG	869976.2	233094.4	1447672	3177.2	7335826
RDHE	648271.5	265105.1	858013.7	1006.41	4187117
RDPUB	1518248	485748.7	2032032	24809.71	9454156
GDP	8000.25	8095.31	3839.07	974.54	14778.91
EDUC	87.66	93.16	16.61	26.43	114.63
EFI	6.82	6.88	0.55	5.01	7.74
FDI	4.56	3.13	6.3	-15.98	50.5

### 3.4. Statistical Models

In order to test the impact of public research on technological innovation, we will first test the effect of each component, i.e., (RDG) and (RDHE). Then, in a second step, we will test the effect of the metric RDPUB. So, the following models will be estimated:

$$PAT_{it+2} = \beta_0 + \beta_1 RDG_{it} + \beta_2 GDP_{it} + \beta_3 EDUC_{it} + \beta_4 EFI_{it} + \beta_5 FDI_{it} + \varepsilon_{it} \quad (1)$$

$$PAT_{it+2} = \beta_0 + \beta_1 RDHE_{it} + \beta_2 GDP_{it} + \beta_3 EDUC_{it} + \beta_4 EFI_{it} + \beta_5 FDI_{it} + \varepsilon_{it} \quad (2)$$

$$PAT_{it+2} = \beta_0 + \beta_1 RDG_{it} + \beta_2 RDHE_{it} + \beta_3 GDP_{it} + \beta_4 EDUC_{it} + \beta_5 EFI_{it} + \beta_6 FDI_{it} + \varepsilon_{it} \quad (3)$$

$$PAT_{it+2} = \beta_0 + \beta_1 RDPUB_{it} + \beta_2 GDP_{it} + \beta_3 EDUC_{it} + \beta_4 EFI_{it} + \beta_5 FDI_{it} + \varepsilon_{it} \quad (4)$$

$i = 1, 2, \dots, 21; t = 1, \dots, 9.$

PAT = Ln(number of patent applications filed in the USPTO); RDG = Ln(R&D expenditures performed by the sector of government); RDHE = Ln(R&D expenditures performed by the sector of higher education); RDPUB = Ln(R&D expenditures performed by government + R&D expenditures performed by higher education); GDP = Ln(GDP per capita); EDUC = Gross enrollment ratio for secondary school; EFI = Economic freedom index; FDI = Foreign direct investment inflows (%GDP);  $\varepsilon$  is regression residuals.

Linear models are estimated by the software STATA 12.

#### 4. PRESENTATION AND INTERPRETATION OF RESULTS

Before presenting findings, we proceed to analyse the independence of the explanatory variables. This is the multi collinearity test. To check the condition of absence of multi-collinearity, we use the simple correlation matrix and assume a limit of 0.8. According to the correlation matrix, strongest correlations are found between the metric relative to public research and its components. The correlation coefficient between RDPUB and RDG is equal to 0.94. The correlation coefficient between RDPUB and RDHE is equal to 0.90. Thus, these two sets of variables should not be introduced in the same model in order to guarantee reliability of results.

##### 4.1. Analysis of Simple Correlations

We begin our analysis by examining simple correlations. The matrix of simple correlations allows us to examine the correlation coefficients in order to study the null hypothesis of the absence of correlation between two variables. Table 2 summarizes the results found.

**Table-2.** Simple correlations between the dependent variable and the explanatory variables.

Simple correlations with the variable log(number of US patent applications)		
Explanatory variables	Predicted sign	Correlation
RDG	+	0.8716***
RDHE	+	0.7384***
RDPUB	+	0.8145***
GDP	+	0.3345***
EDUC	+	0.3926***
EFI	+	-0.1539**
FDI	+/-	-0.0229

Note: \*\* and \*\*\*: significant correlations at 5% and 1% thresholds.

The analysis of simple correlations shows that the variables relative to public research are as expected positively and significantly associated with the innovation level. The level of economic development and the human capital level have the predicted positive sign and are significant. Contrary to the predicted sign, correlation coefficient for EFI is negative and significant. For the FDI variable, the correlation is negative but not significant.

##### 4.2. Findings

To test the impact of public research on innovation level, we have estimated four models where the dependant variable is natural logarithm of patent applications filed in USPTO (PAT) and the explanatory variables of interest are R&D spending by government, R&D spending by higher education and the sum of R&D expenditures by these two sectors.

Before examining results, it is necessary to verify some tests applied on the panel data. First, the homogeneous or heterogeneous specification of the data generating process should be checked. If the test performed (individual presence test) shows that there are individual specificities, the Ordinary Least Squares

(OLS) method is inappropriate and in this case, we apply Hausman test to determine whether the coefficients of the two estimates (fixed and random) are statistically different.

In models (1), (2), (3) and (4) the Lagrange multiplier test gives values of 335.98; 398.19; 280.84 and 286.19 respectively and the associated p-values are below the threshold of 1%. We then reject the null hypothesis of absence of specific effects, so it is necessary to introduce individual effects.

The probability of the Hausman test in models (1), (2) and (3) is  $0.0000 < 1\%$ . Based on the Hausman test, we choose the fixed effects model for these three specifications. In model (4), the probability is equal to 0.0594 which is greater than 1%. So, we choose the random effects model for this specification.

The Breush-Pagan test allows us to detect heteroskedasticity. In models (1), (2) and (3) the probabilities of the test are equal respectively to 0.0033; 0.0000 and 0.0055 confirming the presence of heteroskedasticity problem for these estimated models. In model (4), the probability is equal to 0.2028 which is superior than 1%, confirming the absence of heteroskedasticity problem for this model.

The Wooldridge test allows us to detect the auto-correlation whose null hypothesis is the absence of auto-correlation errors. In models (1), (2), (3) and (4) the probabilities of the test are equal respectively to 0.2506; 0.1852; 0.1410 and 0.1822 confirming the absence of an auto correlation problem for all estimated models.

In the following, we present the results of the linear regressions with correction of the heteroskedasticity problem in the first, second and third specification.

Table 3 provides the results of the four linear regression models.

Table-3. Estimation results of models (1), (2), (3) and (4).

Independent variables	Dependant variable: PAT							
	Specification (1)		Specification (2)		Specification (3)		Specification (4)	
	Coef. $\beta$	SE	Coef. $\beta$	SE	Coef. $\beta$	SE	Coef. $\beta$	SE
Constant	-2.843	4.880***	-21.783	5.271***	-21.796	5.250***	-13.944	2.161***
RDG	0.025	0.143			0.028	0.144		
RDHE			-0.001	0.073	-0.006	0.073		
RDPUB							0.678	0.085***
GDP	2.456	0.638***	2.488	0.646***	2.451	0.679***	0.545	0.248**
EDUC	0.004	0.006	0.004	0.008	0.004	0.008	0.006	0.006
EFI	0.504	0.213**	0.499	0.217**	0.506	0.223**	0.522	0.155***
FDI	-0.003	0.005	-0.003	0.005	-0.003	0.005	-0.005	0.005
Observations	189		189		189		189	
F/Chi2	17.74***		19.31***		16.42***		121.72	
R <sup>2</sup>	0.33		0.33		0.33		0.74	

Note: Coefficients and Standard Errors are given in this table.

\*, \*\*, \*\*\*: Coefficients are significant at 10 %, 5 % and 1 %.

PAT = Ln(number of patent applications filed in the USPTO); RDG = Ln(R&D expenditures performed by the sector of government); RDHE = Ln(R&D expenditures performed by the sector of higher education); RDPUB = Ln(R&D expenditures performed by government + R&D expenditures performed by higher education); GDP = Ln(GDP per capita); EDUC = Gross enrollment ratio for secondary school; EFI = Economic freedom index; FDI = Foreign direct investment inflows (%GDP).

In all specifications, the Fisher/Chi2 statistic testing the joint significance of the explanatory variables is significant at 1%. This allows us to reject the null hypothesis that the regression coefficients  $\beta$  are zero. Therefore, our models are globally significant.

According to the specification (1), the coefficient relative to R&D expenditures performed by the sector of government has the predicted positive sign (0.025). However, this coefficient is not significant. Thus, research performed in public centres has no influence on the level of technological innovation of emerging and developing countries.

According to the specification (2), the coefficient relative to R&D expenditures performed by the sector of higher education is negative and not significant. Thus, research performed in universities has no influence on the level of technological innovation of emerging and developing countries.

In the third model, we introduce the two variables RDG and RDHE. Results confirm the last findings: the effects of each component of public research are not significant.

In model (4), we test the effect on innovation of the sum of research performed by the two sectors. For that, we introduce the variable RDPUB in the model. Findings show that the coefficient relative to this variable is as expected positive and significant at 1% threshold. They imply that an increase in public research by 10% raises the international patenting by 6.78%. Our results corroborate previous studies such as [Beise and Stahl \(1999\)](#) and [Cohen et al. \(2002\)](#). They highlight the importance of public research for technological innovation in emerging and developing countries. Combining the result of this fourth model with those of the precedent models, we can conclude that the components of public research are complementary. Each component is not sufficient to stimulate innovation, but the sum of them encourages more innovative activities. Thus, research conducted by both government sector and higher education sector is a determinant of technological innovation level of emerging and developing countries.

Concerning control variables, we note that the level of economic development and the institutional environment measured by economic freedom index stimulate technological innovation in emerging and developing countries.

## 5. CONCLUSION

The purpose of the present paper was to assess the effect of public research on technological innovation in emerging and developing countries. Analysis of theoretical issues and previous empirical studies allows us to hypothesize that public research will increase the propensity of innovation.

Using linear regressions on panel data, we confirm our hypothesis. Our findings suggest that the sum of research performed by government sector and research performed by higher education sector increases the innovation level of emerging and developing countries. They also suggest that the single effect of the research conducted by each sector has no influence on innovation level.

Our study contributes to the already substantial body of innovation literature. It has important implications, especially on political level. In fact, policy makers desiring to stimulate innovation may want to examine the level of public research as a prerequisite for innovation policy.

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