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EFFICIENCY MEASUREMENT OF R&D SPENDING IN EMERGING COUNTRIES

Kamilia Loukil[1]

[1]*Department of Economics, Faculty of Economics and Management of Sfax, Tunisia*

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ABSTRACT

This paper aims to measure efficiency of R&D spending in ten emerging countries. We estimate two stochastic frontier models where human and physical resources of R&D are the inputs employed to produce an output: patents in the first model and scientific publications in the second model. Empirical evidence shows that scores are higher for publication oriented efficiency than patent oriented efficiency. Moreover, our findings suggest that innovative countries, those with high R&D intensity, are not necessarily efficient in the use of their resources and vice versa.

Contribution/ Originality: The paper's primary contribution is finding that countries with high R&D intensity are not efficient. This implies that an effective public innovation policy must aim not only to increase R&D quantity but also R&D management quality.

1. INTRODUCTION

Innovation is the source of competitive advantage and prosperity for business and countries. That's why it is necessary to study its determinants. Financial capital and human capital were often the main determinants of innovation. This suggests that the more resources devoted to research and development (R&D), the more innovative is the country. However, the economic world is characterized by the scarcity of resources. R&D expenditure cannot be increased indefinitely, but it is necessary to think about making good use of existing resources and using them in an efficient way. In this context, the research questions of our study are: What is the efficiency level of R&D expenditure? Does R&D intensity reflect R&D efficiency level?

The purpose of this paper is to estimate the efficiency of research and development expenditure and to classify ten emerging countries in order to identify particularly efficient countries and particularly inefficient countries.

Many authors have been interested in the issue of R&D efficiency (Wang, 2007; Wang and Huang, 2007; Li, 2009; Chen *et al.*, 2011; Hu *et al.*, 2014). This study aims to enrich the existing literature by focusing on ten emerging countries.

To estimate efficiency scores, we use the stochastic frontier model of Battese and Coelli (1992). The estimation results allow us to quantify R&D efficiency levels and to compare them to R&D intensity levels. Our findings suggest that innovative countries are not necessarily efficient in the use of their resources and vice versa.

The rest of the paper is organized as follows: Section 2 introduces the methodology. Section 3 presents and interprets the results. Section 4 concludes.

2. METHODOLOGY

This paper considers a production framework of R&D activities based on production theory. Each country is considered as a decision unit that employs human and physical resources of R&D as inputs to produce an output such as patents and scientific publications. The stochastic frontier approach is applied to estimate the relative efficiency of R&D of each country.

The R&D production function

Following Griliches (1990) our study considers the international research and development activity in the context of a production function in different countries.

R&D production function of different countries has the following general form:

$$Y_{kt} = f(X_{kit}) \qquad (1)$$

where: k=1,….., K (country), i=1,…., N (inputs), t=1,…..T (years)

Y_{kt} is the R&D output of country k at time t.

X_{kit} is the input i of country k at time t.

The wide variety of inputs resulting from the use of data from different countries requires the use of a flexible functional form. The most used is the translog form.

A translog production function at time t can be written as:

$$\ln Y_{kt} = \beta_0 + \sum \beta_i (\ln X_{kit}) + ½ \sum \beta_{ii} (\ln X_{kit})^2 + ½ \sum \sum\beta_{ij} (\ln X_{kit}) (\ln X_{kjt}) \qquad (2)$$

Where: Y is the output quantity, X_i and X_j are the inputs i and j, respectively. ln is the natural logarithm. β_i β_{ii} and β_{ij} are parameters to be estimated and are independent of countries.

The stochastic frontier model

This research aims to measure the R&D efficiency scores of ten countries. To do this, we use the frontier model of technical efficiency of Battese and Coelli (1992).

The model of Battese and Coelli (1992) may be expressed as:

$$Y_{kt} = f(X_{kt}, \beta) \exp (V_{kt} - U_{kt}), \qquad (3)$$

$$U_{kt} = \eta_{kt} U_k = \{\exp[-\eta (t - T)]\} U_k, t \in Ƥ(k); k = 1, 2, . . ., K; \qquad (4)$$

where: k = 1,…, K country ; t = 1,…, T (year)

Y_{kt} is the production output of k^{th} country at time t.

X_{kt} is a vector (1*i) of production inputs relative to k^{th} country at time t.

β is a vector (i*1) of parameters to be estimated.

V_{kt}'s are assumed to be independent and identically distributed $N(0, \sigma^2_v)$ random errors;

U_k's are assumed to be independent and identically distributed non-negative truncations of the $N(\mu, \sigma^2)$ distribution;

η is an unknown scalar parameter;

and Ƥ(k) represents the set of T_k time periods among the T periods involved for which observations for the *k* th firm are obtained.

The stochastic production frontier model to be estimated in this paper is defined as follows:

$$\ln Y_{kt} = \beta_0 + \sum \beta_i (\ln X_{kit}) + ½ \sum \beta_{ii} (\ln X_{kit})^2 + ½ \sum \sum\beta_{ij} (\ln X_{kit}) (\ln X_{kjt}) + V_{kt} - U_{kt} \qquad (5)$$

where: Y_{kt} is the production output of kth country at time t.

X_{kt} is a vector (1*i) of production inputs relative to kth country at time t.

β is a vector (i*1) of parameters to be estimated.

Parameters are estimated using FRONTIER 4.1 program developed by Coelli (1996).

2.1. Sample Selection

This study considers two empirical models with two different outputs. The first model (Model n°1) will focus on ten emerging countries: Bulgaria, Croatia, Hungary, Latvia, Mexico, Poland, Romania, Russia, South Africa and Turkey. The period covered is 2001- 2010. The second model (Model n°2) will be applied to the same sample during the 2001-2009[1] period. The sample of the study and the periods are selected according to data availability.

2.2. Data

The output of R&D spending is measured by two indicators. (PAT) is the annual number of patent applications filed by the inventors of each country with the United States Patent and Trademark Office (USPTO). The second measure of output is the number of scientific publications (PUB). It is the annual number of papers published in Science Citation Index international journals and the annual number of papers published in Social Sciences Citation Index international journals. These publications were selected by the indicators of science and engineering in 2014 from the National Science Foundation (2014)[2].

The inputs of R&D spending are financial capital and human capital.

The R&D manpower (MRD) measured in full time equivalent is all persons employed directly in R&D as well as those providing direct services related to R&D, such as managers, and administrators (OCDE, 2002).

Concerning the stock of knowledge, the variable introduced reflects the cumulative R&D. For each country, we calculate the stock of research and development (SRD) using the method of perpetual inventory (OCDE, 2001) and based on gross domestic R&D expenditure (in thousands Power Parity Purchase).

Data on inputs are from UNESCO database.

Like Wang (2007) we take two years of difference between the inputs and output data. Thus, in models 1 and 2, data for patents and scientific publications are taken for the periods 2003-2012 and 2003-2011, while data on R&D human capital and R&D financial capital relate to the periods 2001-2010 and 2001-2009, respectively.

3. FINDINGS

Table-1. Mean R&D efficiencies during 2001-2010

Year	Mean efficiency Output = Patents	Mean efficiency Output = Scientific Publications
2001	0.2118	0.3518
2002	0.2271	0.3514
2003	0.2431	0.351
2004	0.2598	0.3507
2005	0.2771	0.3503
2006	0.295	0.3499
2007	0.3134	0.3496
2008	0.3322	0.3492
2009	0.3514	0.3488
2010	0.3838	
Mean efficiency score	0.2872	0.3503

Source: Prepared by the author on the basis of FRONTIER Output

[1] We drop 2010 in this second model because of the lack of data on scientific publications.

[2] National Science Foundation (2014) Science and engineering indicators. National Center for Science and Engineering Statistics, and the Patent BoardTM, Special Tabulation (2013) from Thomson Reuters, SCI and SSCI. Available at http://thomsonreuters.com/products_services/science/

Table-2. Mean R&D efficiencies in the ten emerging countries

Country	Mean efficiency Output = Patents	Mean efficiency Output = Scientific Publications
Bulgaria	0.250	0.143
Croatia	0.215	0.291
Hungary	0.538	0.285
Latvia	0.087	0.113
Mexico	0.374	0.271
Poland	0.158	0.438
Romania	0.115	0.114
Russia	0.159	0.936
South Africa	0.800	0.290
Turkey	0.172	0.618
Mean efficiency score	0.287	0.350

Source: Prepared by the author on the basis of FRONTIER Output

3.1. Average Performance

The analysis of efficiency scores shows that the average performance of innovation systems is low. We also note that the mean efficiency score for scientific publications is the best. In fact, the average value of the scores is 35% for publications and 28.7% for patents, indicating potential improvements in innovation results of 65% and 71.3% respectively, with the same levels of expenditure. Thus, the countries in the sample seem to have more leeway to increase patents than to increase publications. This result is consistent with findings of Wang (2007); Wang and Huang (2007) and Chen *et al.* (2011) where the average technical efficiency is higher when scientific publications are adopted as output rather than patents.

Moreover, we note from Table 1 that the efficiency of innovation systems has remained relatively stable since 2001 (especially in terms of scientific publications).

The Most Efficient Countries

For each innovation indicator, a group of efficient countries emerges.

For patents, the most efficient countries are: South Africa and Hungary.

For publications, the most efficient countries are Russia and Turkey.

The Most Inefficient Countries

For patents, the most inefficient countries are Latvia, Romania and Poland. For scientific publications, the most inefficient countries are Latvia, Romania and Bulgaria.

Note that Romania is among the least efficient countries, regardless of the orientation of efficiency (patents or scientific publications). This result corroborates that found by Chen *et al.* (2011).

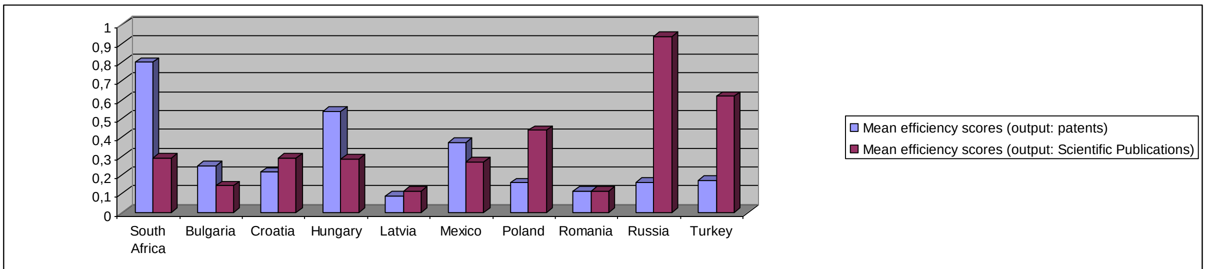

Figure-1. Mean efficiencies for the ten emerging countries

Source: Prepared by the author on the basis of FRONTIER output

Figure 1 compares the efficiency scores obtained for each of the innovation indicators and shows that some countries such as Turkey, Russia and Poland are much more efficient in terms of scientific publications than patents.

3.2. Performance at the individual level

At the individual level, the level of efficiency varies between countries according to the potential for innovation (see Table 3).

Table-3. Innovation level and efficiency level in the ten emerging countries

Country	GERD (% GDP)	Patent oriented efficiency		Publication oriented efficiency	
		Mean score	rank	Mean score	rank
Bulgaria	0.476	0.250	4	0.143	8
Croatia	0.87	0.215	5	0.291	4
Hungary	0.987	0.538	2	0.285	6
Latvia	0.473	0.087	10	0.113	10
Mexico	0.392	0.374	3	0.271	7
Poland	0.595	0.158	8	0.438	3
Romania	0.444	0.115	9	0.114	9
Russia	1.155	0.159	7	0.936	1
South Africa	0.814	0.800	1	0.290	5
Turkey	0.638	0.172	6	0.618	2

Source: Prepared by the author on the basis of FRONTIER Output and EUROSTAT Database

Patent-Oriented Efficiency

Russia and Croatia have the highest levels of domestic R&D spending but have a low average level of efficiency (ranked 7th and 5 th respectively). Mexico is weakly innovative (in terms of share of gross R&D spending in GDP), yet it is ranked among the top countries in terms of efficiency. It is in the 3rd place.

Hungary and South Africa are the most innovative countries in our sample and are also ranked among the most efficient countries, with ranks 2 and 1, respectively.

Scientific Publication-Oriented Efficiency

The results show that Russia is the country with the greatest potential for innovation and is also the most efficient. However, although Hungary and South Africa have strong potential for innovation (in terms of R&D share in GDP), they are ranked sixth and fifth in terms of efficiency.

Romania and Mexico are the least innovative countries in our sample and are also ranked among the most inefficient countries.

4. CONCLUSION

After estimating R&D efficiency scores, our study shows that emerging countries are lowly efficient in the use of their R&D resources. Results suggest that an innovative country is not necessarily efficient. Our analysis has important implications for policy makers. In fact, an effective public innovation policy must aim not only to increase innovation but also R&D efficiency. Our analysis also shows that the efficiency of innovation systems has remained relatively stable since 2001 (especially in scientific publications), indicating that improving efficiency is not a top priority for the government agenda and innovation policies, which is harmful for emerging countries.

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