Innovation as a competitive differential based on investments in R&D by GII countries: A contributing to the global efficiency as to the Data Envelopment Analysis (DEA)

*Paulo Ricardo Cosme Bezerra, PhD Student
Post-Graduation Program in Science and Engineering of Petroleum – UFRN - Brazil
paulorcbezerra@gmail.com

Dr. Mariana Rodrigues de Almeida
Post-Graduation Program in Production Engineering – UFRN - Brazil
almeidamariana@yahoo.com.br

1. Introduction

Innovation is considered the main factor that allows the societal masses and economies to solidly become more developed. The designated "new growth theory", and the criticism given by it, were brought, in fact, to put innovation as the center of a new economical and developmental growth model, in which the ability to produce, disseminate, absorb and recombine knowledge has an essential role (FERRAO, 2002).

According to Rolim (2003), the emphasis in innovation as a responsible for the economical differences among countries takes an ever-growing spot in economical literature. The many different ways innovation is focused turns it into a fundamental piece in its analytical elaborations. It is present in discussions on the national systems of innovation, the so called evolutionist economy (LUNDVALL, 1992), in the industrial *clusters* discussion (PORTER, 1990), in the theory of regulation from the economists point of view (AMABLE *et al*., 1997), of the authors that work along with industrial districts (BECATTINI, 1991) and even from the perspective of the neoclassical economy authors (ROMER, 1990).

In this context, innovation stands out associated to the idea of scientific discovery because of the referred investigation and development activities, executed inside businesses, investigation institutions or universities. Innovation processes occur when, based on this discovery and the making of experimental nature prototypes, it is possible to widen determined methodological procedures, which allows transforming the discovery in some kind of generic technological knowledge. In other words, potentially appropriable by any entity that can benefit from it for the activities they develop. This way of perceiving the innovation process is clearly sequential, hierarchical and descendant.

The objective this article is to analyze the efficiency of countries from 2012 to 2014. For this purpose, the *Global Innovation Index* was used, in which INSEAD (The Business School for the Word) and WIPO (World Intellectual Property Organization) realized how innovation has a fundamental role in the economic growing and development thus developing the *Global Innovation Index* (GII) to understand the innovation parameters and its behaviors (ALMEIDA, 2010).

Data Envelopment Analysis (DEA) is a mathematical programming technique that analyses the performance, in relative efficiency terms, of different Decision Making Units (DMUs), based on a group of *inputs* and *outputs.* DMUs located at the borders of efficiency will serve as a *benchmark* for the others. The origins of the DEA are unraveled by Forsound and Sarafoglou (2002) and was developed initially by Charnes, Cooper and Rhodes (1978), based on the principles derived from the model of Farrell (1957).

Efficiency of a productive unity is measured by comparison between values observed, optimal input, and output values. This comparison can be done, in general, resolving the reason between the amount of products generated and the minimum amount of resources required. The combination of the two of them can provide useful information with Chart 1.

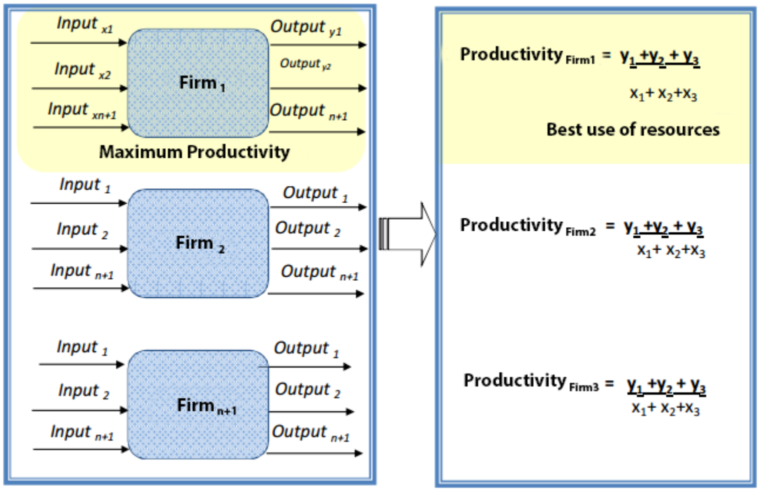

Chart 1 – Efficiency measurement scheme

2. DEA's Classic Modeling

2.1. There are two Classic DEA models: CCR and BCC

- **CCR Model**

This model is also known as CRS or Constant Returns to Scale (Charnes et. al., 1978). In its mathematical formula each DMU *k* is a unit of production that uses *n* inputs x_{jk}, $j=1,\dots, n,$ to produce *m* outputs y_{ik}, $i=1,\dots, m$.

Primal CCR Model (Multipliers Form)	Input oriented	$Max = \sum_{i=1}^{m} u_i \times y_{i0}$
		$S.a.$
		$\sum_{i=1}^{m} u_i \times y_{ik} - \sum_{j=1}^{n} v_j \times x_{jk} \leq 0 \quad fo \quad k = 1,2,\dots,z$
		$\sum_{j=1}^{n} v_j \times x_{j0} = 1$
		$u_i \ e \ v_j \geq 0, i = 1,\dots,m, j = 1,\dots,n$
			Variables
			
			ui = Output utility i;
			vj = Input utility j;
			xjk = input quantity k DMU's i;
			xj0 = input quantity j from DMU under analysis;
			yj0 = input quantity i from DMU under analysis;
			z = Number of units under evaluation;
			m = Number of outputs;
			n = Number of inputs

	Output oriented	$Min = \sum_{j=1}^{n} v_i \times x_{j0}$ $S.a.$ $\sum_{i=1}^{m} u_i \times y_{ik} - \sum_{j=1}^{n} v_j \times x_{jk} \leq 0 \quad fo \quad k = 1,2,\dots,z$ $\sum_{i=1}^{n} u_i \times y_{i0} = 1$ $u_i \ e \ v_j \geq 0, i = 1,\dots,m, j = 1,\dots,n$	

Table 01 - Primal CCR Model (Multipliers Form)

- **BCC Model**

BCC model (Banker *et al*., 1984), also called VRS (Variable Returns to Scale, considers production efficiency situations with variation in scale and is not proportional between inputs and outputs.

Primal BCC Model (Multipliers Form)	Input oriented	$Max = \sum_{i=1}^{m} u_i \times y_{i0} + u$ $S.a.$ $\sum_{i=1}^{m} u_i \times y_{ik} - \sum_{j=1}^{n} v_j \times x_{jk} \le 0 \quad to \quad k = 1,2,\ldots,z$ $\sum_{j=1}^{n} v_j \times x_{j0} = 1$ $u_i \; e \; v_j \ge 0, i = 1,\ldots,m, j = 1,\ldots,n$	Variables ui = weight calculated for the product i; vj = weight calculated for the product j; xjk = input quantity j for unity k; yjk = product quantity i for unity k; xj0 = input quantity j for unity under analysis; yj0 = product quantity i for unity under analysis; z = Number of units under evaluation; m = Number of types of prod-ucts; n = Number of types of inputs; e, u and v = scaled return coeffi-cients
	Output oriented	$Min = \sum_{j=1}^{n} v_i \times x_{j0} + v$ $S.a.$ $\sum_{i=1}^{m} u_i \times y_{ik} - \sum_{j=1}^{n} v_j \times x_{jk} \le 0 \quad to \quad k = 1,2,\ldots,z$ $\sum_{i=1}^{n} u_i \times y_{i0} = 1$ $u_i \; e \; v_j \ge 0, i = 1,\ldots,m, j = 1,\ldots,n$	

Table 02 - Primal BBC Model (Multipliers Form)

3. Research Methodology

Statics is a group of methods for planning experiments, acquire data and organize, review, analyze, interpret and extract conclusions from them (TRIOLA, 1999).

In this article, following the research methodology, the descriptive analysis and its correlation is accomplished; it utilizes the *Stepwise* method for the variables selection; the BCC and CCR models are applied; the benchmarking is determined and the result analysis is finally done. The *World Economic Forum* report for the international competitiveness also known as *Global Competitiveness Report (GCR) 2012-2014: Full Data Edition* was chosen as a source of data.

GII presents five enabling pillars that define the aspects of a proper environment for innovation in economics: Institutions, Human Capital and Research, Infrastructure, Market Sophistication and Business Sophistication. The innovation products, on the other hand, are a result of the innovating activities inside the economy, including knowledge and technology production, and creativity.

In this model, the Decision Making Units are 135 countries in a period between 2012 and 2014. For such purpose, the Global Innovation Index database was used as presented in the following chart:

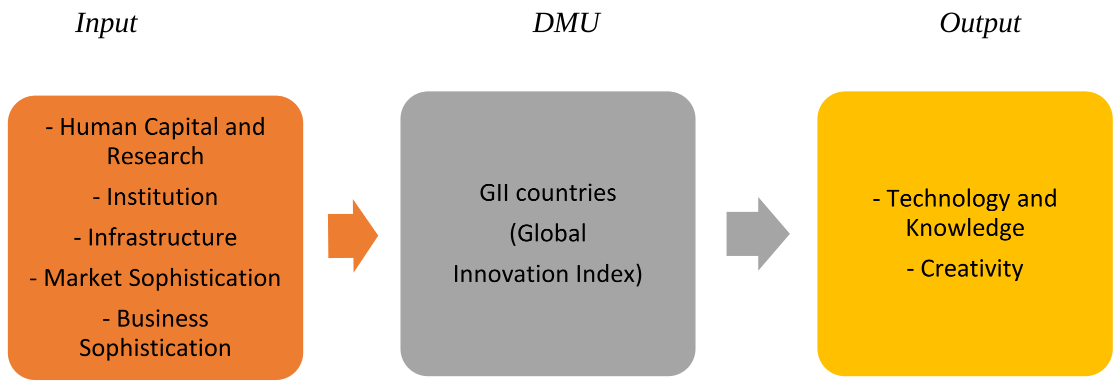

Chart 2 – Input/output oriented transformation model

4. Results

The descriptive statistical analysis of inputs and outputs analyzed by the *Global Innovation Index* (GII), of countries in the period between 2012 and 2014 are presented in the following. In 2012, it was verified that the results are not equally distributed for they show a data coefficient variation greater than 25% and are too far apart when compared to the average, following the same behavior in 2013 and 2014.

Using Pearson's coefficient correlations described between inputs and outputs were found, therefore having a strong positive correlation between variables contained in the research. After this step, Stepwise analysis was considered. However, given the level of people involved in the reduction of inputs and outputs of the system, and considering that the index is already composed of various subdivisions previously studied, not using Stepwise analysis would be preferable. That, as suggested by Wagner and Shimshak (2007), would be a model with simple rules to remove variables (regressive mode) or add variables (progressive mode) into the DEA model, one at a time.

Table 3 shows the CCR and BCC models calculated with a radial distance limiting the results to the maximum number of one.

Table 3 – Results of the models CCR and BCC application, calculated using radial distance for the years of 2012, 2013 and 2014.

Year	**Method**	**Average**	**Standard Deviation**	**Minimum**	**Maximum**	**Percentage (%)**		
						25	**50**	**75**
2012	CCR	0,81	0,12	0,48	1,00	0,74	0,81	0,92
	BCC	0,88	0,10	0,65	1,00	0,80	0,88	0,99
2013	CCR	0,82	0,13	0,51	1,00	0,73	0,80	0,94
	BCC	0,86	0,11	0,64	1,00	0,78	0,86	1,00
2014	CCR	0,82	0,15	0,13	1,00	0,73	0,84	0,94
	BCC	0,89	0,10	0,62	1,00	0,81	0,90	1,00

One of the analysis done was suggested by Barbosa (2012), who grouped DMUs according to levels of efficiency, classifying as weak, reasonable, good, great and excellent, defined by the quartiles from the efficiency score series. DMUs with efficiency equal to one are classified as excellent, the remaining are classified as the following:

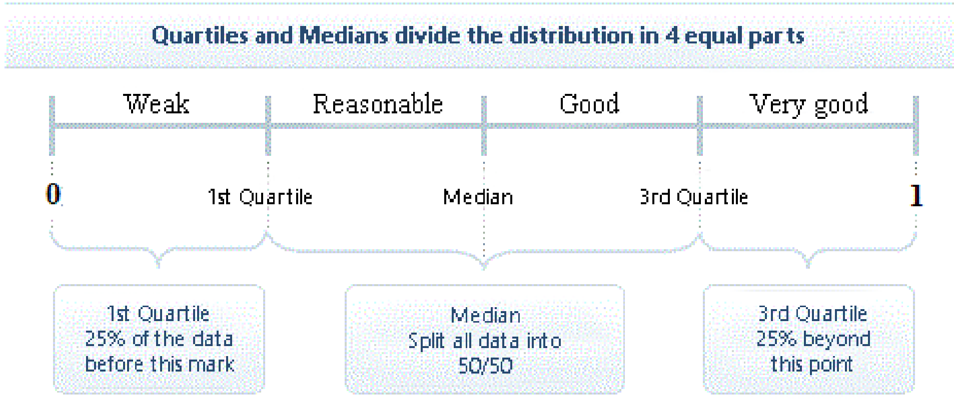

Chart 3 – Grouping of DMUs by efficiency levels

5. Conclusions

This article sought to evaluate the efficiency of the countries presented in the GII regarding their performance in competitivity and technological innovation. To analyze the results, Data Envelopment Analysis (DEA) is utilized through input oriented BCC (Variable Returns to Scale) and CCR (Constant Returns to Scale).The variable dispersion analysis shows that the data is not equally distributed for presenting a variation coefficient superior to 25% and through Pearson's coefficient correlations have been found and it's being verified that there is a strong positive correlation between variables in the study.

About the definition of orientation (input/output oriented) – The orientation is up to the data analyst – can be oriented to the output. In addition to the model variation (CCR and BBC are the main models) DEA also changes depending on the orientation, which can be input or output. All the applications of this article were done with an input orientation. This type of orientation is common in literature.

It is necessary to more deeply understand the efficient units by determining the efficiency, it is also important to verify which ones were benchmarked to set a pattern for the other inefficient countries.

Using the CCR method in the year of 2012, sixteen countries were evaluated as efficient, being Moldova a benchmark for other ninety five countries (70,37% of them). China for other thirty seven countries (27,41% of them) and Ivory Coast is reference for other twenty nine countries (21,48% of them).

By the CCR method in the year of 2013, twenty one countries were evaluated as efficient, being Nigeria a benchmark for other fifty two countries (38,52% of them). Moldova for other fifty one countries (37,78% of them) and Malta for forty seven countries (34,81% of them). By the BCC method in 2013, there are twenty-nine efficient countries. Being Moldova a benchmark for other forty-four countries (32,59% of them), Mali is a benchmark for other forty three countries (31,85% of them) and Nigeria for other thirty-seven (27,41% of them).

About the results from CCR method in 2014, twenty-four countries were evaluated as efficient, being Moldova a benchmark for other eighty-two countries (60,74% of them), Malta for other forty-five countries (33,33% of them) and China for forty-one countries (30,37% of them). By the BCC method in 2014, there are thirty efficient countries. Venezuela is a benchmark for sixty countries (44,44% of them), Moldova is a benchmark for other forty-six countries (34,07% of them) and Pakistan is a benchmark for thirty-nine countries (28,29% of them).

REFERENCES

ALMEIDA, Mariana R. de. (2010). A eficiência dos investimentos do programa de inovação tecnológica em pequena empresa (PIPE): uma integração da Análise Envoltória de Dados e Índice Malmquist. **Tese de Doutorado da Escola de Engenharia de São Carlos da Universidade de São Paulo**. São Carlos.

AMABLE, B.; BARRÉ, R.; BOYER, R.(1997). **Les systèmes d'innovation à l'ère da la globalisation**. Paris: Economica.

BARBOSA, A. (2012). **Pode a regulação econômica melhorar o desempenho econômico financeiro e a universalização dos serviços de águas e esgotos no Brasil?** Brasília: SEAE, 67p.

BECATTINI, G. (1991). The industrial district as a creative milieu. In: BENKO, G.; DUNFORD, M. **Industrial Change and Regional Development**. London: Pinter, p. 102-114.

BANKER, R.D., CHARNES, A. & COOPER, W.W (1984) - Some models for estimating technical scale inefficiencies in Data Envelopment Analysis. **Management Science** Vol. 30, n. 9, p. 1078-1092.

CHARNES, A., COOPER, W.W. & RHODES, E. (1978) - Measuring the efficiency of decision-making units. **European Journal of Operational Research** Vol. 2, p. 429-444.

FARRELL, M. J. (1957) The Measurement of Productive Efficiency. **Journal of the Royal Statistical Society**. Series A (General), v. 120, n. 3, p. 253-290.

FERRÃO, J. (2002). Inovar para desenvolver: o conceito de gestão de trajectórias territoriais de inovação. **Revista Internacional de Desenvolvimento Local**. Vol. 3, N 4, pp 17-26, Março.

FORSUND, F.; SARAFOGLOU, N. (2002). On the origins of Data Envelopment Analysis. **Journal Productivity Analysis**. Vol. 17 nº 1/2.pp 23-40.

LUNDVALL, B. (1992). National Systems of Innovation: **towards a theory of innovation and interactive learning**. London: Pinter.

PORTER, M. (1990). **The Competitive Advantage of Nations**. New York: Free press.

ROLIM, C. É possível a existência de sistemas regionais de inovação em países subdesenvolvidos? **Revista de Economia**. Vol. 28/29, pp 275 – 300, 2003.

ROMER, P. (1990). Endogenous Technological Change. **Journal of Political Economy**, n. 98, p. 70-102.

WAGNER J. M.; SHIMSHAK, D. G. (2007). Stepwise selection of variables in data envelopment analysis: procedures and managerial perspectives. **European Journal of Operation Research**, vol. 180, p. 57-67.

TRIOLA, M. F. (1999). **Introdução a Estatística**. Rio de Janeiro, LTC.