Vol. VI, Issue 3
June 2016

Technological Innovation in Developing Countries: A Descriptive Analysis

Author: **Kamilia Loukil**, Faculty of Economics and Management of Sfax, Tunisia, loukilkamilia2005@yahoo.fr

Although most studies are interested with innovation in developed countries, we think that innovation is also vital for developing ones. The objective of this study is to describe it in developing countries. To quantify innovations, we use two types of indicators. The first type is associated with the inputs (R&D), the second is associated with outputs (patents and scientific publications). We find that developing countries have made progress in terms of innovation, but are still far from world leaders. We find also that the BRIC countries, especially India and China, are the most efficient in terms of scientific and technological power.

Keywords: *developing countries, innovation, patents, R&D expenditures, scientific publications.*

Introduction

Two main reasons explain why technological innovation is crucial for Developing Countries (DC): it allows economic growth to occur and poverty to be reduced.

The important role of innovation in economic growth was highlighted for the first time by Schumpeter. However, his work was not reflected in the first business models. In 1956, [1] emphasized that increases in capital and labour are not solely responsible for economic growth. There is another factor that represents the technical change and improves the productivity of capital and labour. Therefore, the technology was enclosed as a separate factor that increases the productivity of capital and labour. However, technology was supposed exogenous.

[2] models technology not as manna from heaven but as result of an explicit effort. Thus, the new growth theory models technology as a result of explicit inputs, including Research and Development (R&D) and human capital.

Moreover, the approach of the technological gap is developed in the 1980s. Economists study the process of catching up of some countries with developed countries, focusing on the creation and the international dissemination of new technologies ([3]; [4]).

In order to reduce poverty, developing countries must invest in three main areas: agriculture, health and environment. To address the problems in these sectors, DC must find innovative solutions.

Developing countries are innovating to varying degrees. To quantify their innovations, we use two types of indicators. The first type is associated with the inputs (R&D), the second is associated with outputs (patents and scientific publications).

R&D Expenditures

Expenditures on R&D are the main inputs of the innovation activity. The new growth theory suggests that innovation depends mainly on scientists and engineers engaged in R&D and existing knowledge ([5], [6], [7], [8]).

The R&D efforts are usually measured in terms of R&D expenditures or according to the number of employees in these activities. If both measures can reflect the flow of resources devoted to development of innovation, they nevertheless remain imperfect for assessing corporate innovation effort. Indeed, such a measure does not take account that the innovation is risky, so that a significant portion of R&D projects is unsuccessful, and the discovery of new technologies by chance is possible. In addition, a significant gap can exist between the expenditures of R&D and delivery of commercially viable product. Another disadvantage of this measure is that the data is only available for a relatively small number of countries over a reasonable period of time ([9]).

To describe R&D expenditures and staff in DC, we consulted the UNESCO database. Table 1 summarizes the evolution of these two measures of innovation between 2005 and 2010 in 22 countries.

From this table, we note that China ranks first in terms of innovation inputs. In fact, in 2010 the share of R&D expenditures in GDP is equal to 1,73%. Its scientists and engineers are 2553829.

In terms of R&D, Brazil, Hungary and Russia are the best performers in 2010 after China, with shares in GDP equal to 1,16 ; 1,15 and 1,13 respectively.

The Central and East European countries do not reach the European target of 3% of GDP investment in favour of R&D. They are still very far from that objective.

Table 1: Inputs of innovation in 22 DC (2005-2010)

	R&D expenditure (% GDP)			R&D scientists and engineers		
Country	**2005**	**2010**	**Change 2005-2010 (%)**	**2005**	**2010**	**Change 2005-2010 (%)**
Argentina	0,38	0,49	28,95	45361	65761	44,97
Brazil	1	1,16	16	196283	266709	35,88
Bulgaria	0,45	0,59	31,11	15853	16574	4,55
China	1,32	1,73	31,06	1364799	2553829	87,12
Croatia	0,86	0,74	-13,95	9270	10859	17,14
Ethiopia	0,18	0,24	33,33	5112	8282	62,01
Guatemala	0,04	0,04	0	851	876	2,94
Hungary	0,93	1,15	23,66	23239	31480	35,46
India	0,81	0,8	-1,23	391149	441126	12,78
Kuwait	0,1	0,1	0	800	829	3,63
Latvia	0,52	0,61	17,31	5483	5563	1,46
Lithuania	0,75	0,78	4	11002	12315	11,93
Madagascar	0,18	0,11	-38,89	1686	1785	5,87
Moldova	0,4	0,44	10	4672	4316	-7,62
Pakistan	0,44	0,39	-11,36	53159	72537,5	36,45
Panama	0,25	0,15	-40	1302	712	-45,31
Poland	0,57	0,72	26,32	76761	81843	6,62
Romania	0,41	0,46	12,2	33222	26171	-21,22
Russia	1,07	1,13	5,61	919716	839992	-8,67
South Africa	0,86	0,74	-13,95	28798	29486	2,39
Thailand	0,23	0,32	39,13	36967	56733,5	53,47
Turkey	0,59	0,84	42,37	49251	81792	66,07

Source : UNESCO

In terms of evolution, we note that between 2005 and 2010, R&D expenditures and staff are experiencing a trend towards increasing in some countries and a downward trend in others.

In terms of R&D, it is Turkey that has experienced the most significant positive development with a growth rate of over 42%, followed by Thailand and Ethiopia (with growth rates of over 39% and 33% respectively). In Guatemala and Kuwait, the share of R&D spending in GDP did not change between 2005 and 2010. India has decreased slightly: Expenses decreased from 0,81% of GDP in 2005 to 0,8% in 2010, a rate of decline of 1,23%. The largest drop is registered in Panama where expenditures on research decrease from 0,25% of GDP to 0,15%, a decrease of 40% in 2010 compared to 2005.

In terms of R&D scientists and engineers, the number of researchers in China has increased from 1364799 in 2005 to 2553829 in 2010, an increase of over 87%. This is the highest growth rate among the 22 countries surveyed. Turkey and Ethiopia are in second and third place, with growth rates of 66% and 62% respectively. The R&D staff in Moldova, Russia, Romania and Panama declined between 2005 and 2010 by 7%, 8%, 21% and 45% respectively.

Patents

While technological innovation cannot be measured exactly, patenting is often considered a suitable proxy to the level of innovation ([10], [11], [12], [13]).

The choice of patents as a proxy for output of innovation is justified by several advantages. The first advantage is the availability of temporal series which are very long for nations and regions. The second relates to databases on patents which are easily accessible to the public. The data are classified in detail by technical field. In addition, the patent applications provide the most comprehensive and the most detailed insight on technical knowledge over long periods.

However, this measure has some limits. First, the patent indicator is missing several unpatented inventions since some technology types are not patentable. On the other hand, the patents do not measure the economic value of technology ([14], [15], [16]).

Table 2 below illustrates change in the number of patents granted by the USPTO to inventors from developing countries during the period 2000-2013. From this table, we see that the number of patents is continuously increasing until 2005 when it decreases slightly compared to the previous year, a decrease of 7%. In 2006, it resumed its pattern growth to record the highest growth rate in 2010, a rate of 30%. Currently, patents granted to DC are 11867.

Table 2: Evolution of patents in DC (2000-2013)

	Number of patents	**Growth rate**
2000	1271	
2001	1557	18%
2002	1757	11%
2003	1983	11%
2004	2052	3%
2005	1910	- 7%
2006	2641	28%
2007	3002	12%
2008	3833	22%
2009	4312	11%
2010	6180	30%
2011	6941	11%
2012	9318	25%
2013	11867	21%

Source : USPTO

Regarding the distribution of these patents, Fig. 1 shows that there is a great disparity between Asia on the one hand and the other regions on the other. In fact, Asia is the dominant region with a share equal to 80%. This is explained by the greater contribution of India and China whose innovations reach 9071, more than 76% of total developing countries innovations.
For the four regions with 20% of DC's innovations, we observe that sub-Saharan Africa is the least innovative (2% of the total number of patents).

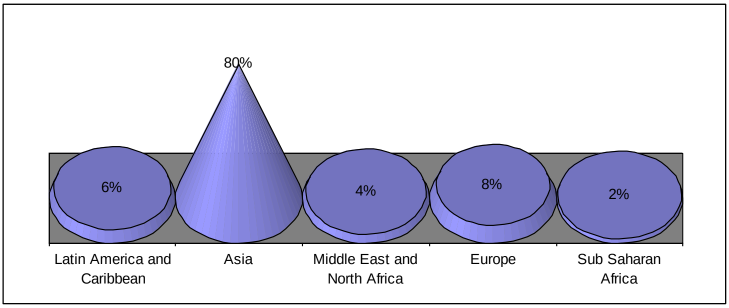

Figure 1: Patents granted by the USPTO to DC by region in 2013

Patents : International Comparison

For a more detailed analysis of the level of innovation in developing countries, international comparison is necessary.

Table 3 presents 5-year average percentage changes for US patents granted to inventors from 30 DC. An overall average for three periods covering 1998-2013 is also presented. As can be seen from Table 3, Egypt ranks first with the highest variation of the patents from 1998 to 2013 (a change rate equal to 677,8%). Turkey, China, Saudi Arabia and India fill the following ranks. In Bahamas, Peru and Venezuela, the rate of change in the number of patents has decreased.

In terms of absolute number of patents in 1998, there is a divergence between countries (see Fig. 2). In fact, Russia has the largest number of patents (194), followed by South Africa (132). Other countries form two groups. A first group is characterized by an average number of patents. It consists of 7 countries: Brazil, China, India, Mexico, Hungary, Argentina and Malaysia. A second group comprises the remaining countries where the number of patents is low.

Over the years, the landscape has changed. Indeed, in 2013 we see a grouping of countries, with the exception of China and India (see Fig. 3). China occupies the leading position with 6597 patents, followed by India with 2474 patents.

Table 3: US patents by country of origin

	Number of patents				Change	Change	Change	Change
Country	**1998**	**2003**	**2008**	**2013**	**1998-2003** (%)	**2003-2008** (%)	**2008-2013** (%)	**1998-2013** (%)
Argentina	46	70	42	80	52,2	-40	90,5	34,2
Bahamas	10	11	4	6	10	-63,6	50	-1,2
Brazil	88	180	133	286	104,5	-26,1	115	64,5
Bulgaria	4	11	18	30	175	63,6	66,7	101,8
Chile	17	15	20	57	-11,8	33,3	185	68,9
China	88	424	1874	6597	381,8	342	252	325,3
Colombia	4	11	13	21	175	18,2	61,5	84,9
Costa Rica	5	10	13	9	100	30	-30,8	33,1
Croatia	14	13	17	18	-7,1	30,8	5,9	9,8
Cuba	5	7	6	13	40	-14,3	116,7	47,5
Egypt	1	6	2	34	500	-66,7	1600	677,8
UA Emirates	1	3	10	19	200	233,3	90	174,4
Hungary	52	72	72	141	38,5	0	95,8	44,8

India	94	356	672	2474	278,7	88,8	268,2	211,9
Indonesia	10	12	19	15	20	58,3	-21,1	19,1
Kuwait	6	7	15	86	16,7	114,3	473,3	2014
Malaysia	35	63	168	230	80	166,7	36,9	94,5
Mexico	77	93	77	204	20,8	-17,2	164,9	56,2
Peru	5	4	5	3	-20	25	-40	-11,7
Philippines	19	25	22	34	31,6	-12	54,5	24,7
Poland	19	19	68	113	0	257,9	66,2	108
Romania	3	7	12	60	133,3	71,4	400	201,6
Russia	194	203	181	432	4,6	-10,8	138,7	44,2
Saudi Arabia	14	19	31	239	35,7	63,2	671	256,6
South Africa	132	131	124	181	-0,8	-5,3	46	13,3
Thailand	21	47	40	104	123,8	-14,9	160	89,6
Turkey	2	32	35	83	1500	9,4	137,1	548,8
Ukraine	17	15	21	38	-11,8	40	81	36,4
Uruguay	3	2	2	10	-33,3	0	400	122,2
Venezuela	29	20	16	16	-31	-20	0	-17

Source: Author's calculations using USPTO

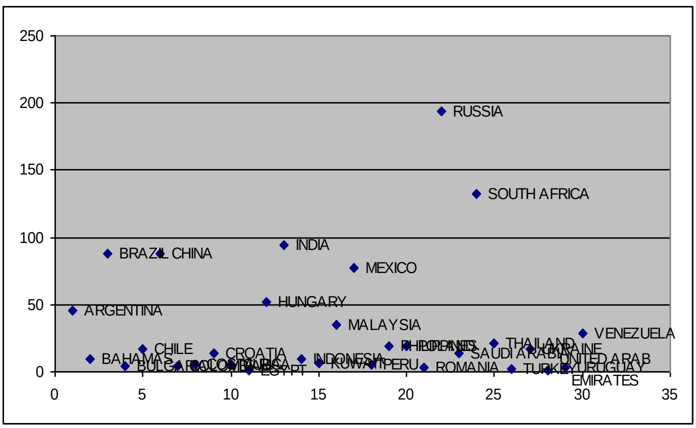

Figure 2: US patents in 30 DC for 1998

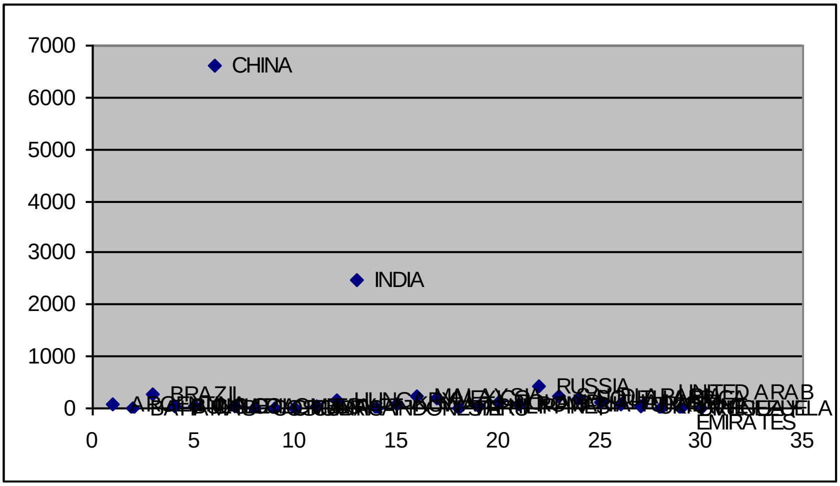

Figure 3: US patents in 30 DC for 2013

Compare now all DC observed with developed countries. As indicated in Table 4, for the period 1998-2013, the total number of patents in the world is growing on average by 25,7% (The leading players in the global total number of patents are Germany, the United States and Japan. They are chosen on the basis of the sum of patents during the period 1998-2013).

On the contrary, the average change observed for the 30 countries is 131,8%. Developing countries increase their share in world patents from 62,3% in 1998 to 84,2% in 2013, which is an impressive performance. But it is disappointing to see that in 2013, the share of all DC observed is not even that of a single OECD country (Germany). Developing countries have made significant progress, but they still have a long way to go.

Table 4: US Patents : Comparison developing / developed countries

	Number of patents				Change 1998 - 2003 (%)	Change 2003 - 2008 (%)	Change 2008 - 2013 (%)	Change 1998 - 2013 (%)
Country	**1998**	**2003**	**2008**	**2013**				
30 DC total	1015	1888	3732	11633	86	97,7	211,7	131,8

total issues US patents	163204	187048	185244	302962	14,6	-1	63,5	25,7
Germany	9582	12140	10085	16605	26,7	-16,9	64,7	24,8
United States	90697	98590	92001	147666	8,7	-6,7	60,5	20,8
Japan	32118	37248	36679	54170	16	-1,5	47,7	20,7
As share of total issues US patents (%)								
30 DC	0,6	1	2	3,8	62,3	99,6	90,6	84,2
Germany	5,9	6,5	5,4	5,5	10,5	-16,1	0,7	-1,6
United States	55,6	52,7	49,6		-5,2	-5,8	-1,9	-4,3
Japan	19,7	19,9	19,8	17,9	1,2	-0,6	-9,7	-3

Source: Author's calculations using USPTO

Scientific publications

The number of scientific publications of a country constitutes a significant measure of its scientific capacity. Numerous studies conduct bibliometric analysis and use this measure ([17], [18], [19]). In this paper, we use international scientific publications of journals indexed by the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI) Thomson Reuters. (The data source for scientific publications is NSF 2014 : National Science Foundation, 2014 National Science and engineering indicators. Center for Science and Engineering Statistics, and the Patent BoardTM, Special Tabulation (2013) from Thomson Reuters, SCI and SSCI). These indices are considered the most reliable measures and the more used to observe the scientific power of countries ([18], [19], [20]). Such publications are a source of comparable data at international scale. In addition, they enjoy a minimum standard of international quality.

The major disadvantages of this measure are: (a) the propensity to publish varies across disciplines; (b) the publications based on the most important journals in the world are likely to under-represent the scientific activities in developing countries; (c) the majority of journals under the control of SciSearch are written in English, posing a problem of language to authors from non-English speaking countries ([21]).

Table 5 describes the evolution of the number of scientific articles published by researchers from developing countries during the period 2000-2011.

Table 5: Evolution of scientific publications in 30 DC (2000-2011)

	Number of scientific publications	Growth rate
2000	90168,2	
2001	93694,2	4%
2002	100562,8	7%
2003	109185,1	8%
2004	120010	9%
2005	131088,6	8%
2006	144464,7	9%
2007	158025,3	9%
2008	171386	8%
2009	181851,9	6%
2010	189787,7	4%
2011	207200,1	8%

Source : NSF 2014

From the table above, we see that scientific publications have continued to increase over time. This increase is however less intensive than that of patents. In fact, the highest growth rate is 9% against 30% for patents. In 2011, the publications of DC are 207200,1.

Regarding the distribution of these publications, we note a disparity between regions, similar although less intensive than that observed in the case of patents (see Fig. 4). Indeed, sub-Saharan Africa is the worst performing region. By contrast, Asia remains the most promising region in terms of scientific articles. We record once again the China's dominance that has a share close to 75% followed by India with a share of 19%. Recall that the China's share of patents in the Asian region is almost equal to 76% in 2013. Thus, this country produces as many patents as scientific publications. It is the most efficient among all developing countries in technological power and scientific power.

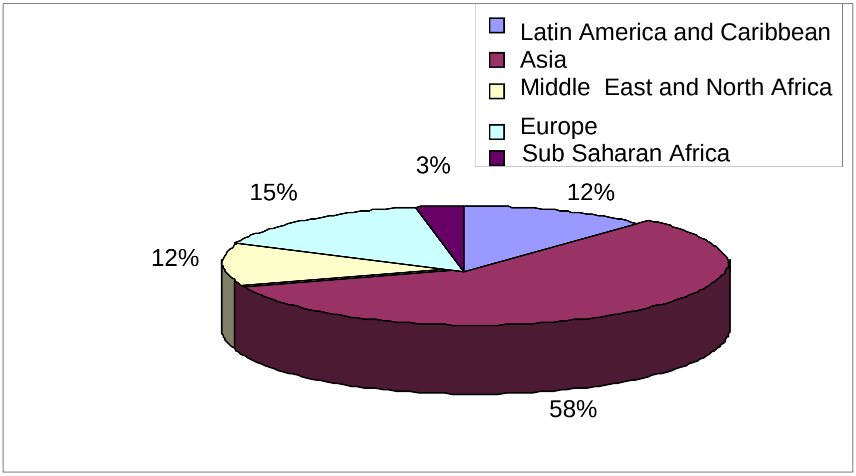

Figure 4: Scientific publications in DC by region for 2011

Scientific publications: International comparison

Table 6 presents 4-year average percentage changes for scientific publications of 30 developing countries. An overall average for three periods covering 1999-2011 is also presented.

As the table shows, Iran is in first place with the highest variation between 1999 and 2011 (a change rate equal to 133,5%). China, Malaysia, Pakistan and Thailand have the following ranks. In Morocco, Russia, Bulgaria, Ukraine, Belarus and Venezuela, the rate of change in the number of scientific articles has decreased.

Table 6: Scientific publications by the author's country of residence in 30 DC (1999-2011)

Country	Number of scientific publications				Change 1999-2003 (%)	Change 2003-2007 (%)	Change 2007-2011 (%)	Change 1999-2011 (%)
	1999	2003	2007	2011				
Algeria	185,4	280,7	480,7	599,3	51,4	71,3	24,7	49,1
Argentina	2635,8	2919,8	3364,3	3862,8	10,8	15,2	14,8	13,6
belarus	578,6	520,6	411,5	341,6	-10	-21	-17	-16

Brazil	5859,3	8330,2	11890,8	13148,1	42,2	42,7	10,6	31,8
Bulgaria	867,3	774,7	801,4	650,3	-10,7	3,4	-18,9	-8,7
Chile	1058,9	1406,4	1741,2	1979,2	32,8	23,8	13,7	23,4
China	15714,7	28767,9	56811,2	89894,4	83,1	97,5	58,2	79,6
Colombia	240,3	325,5	489,4	726,6	35,5	50,4	48,5	44,8
Croatia	647,1	798,3	1101,6	1288,6	23,4	38	17	26,1
Egypt	1293	1716,8	1934,4	2514,9	32,8	12,7	30	25,2
Hungary	2199,6	2450,7	2452,1	2289,3	11,4	0,1	-6,6	1,6
India	10190,4	12462,2	18202,9	22480,5	22,3	46,1	23,5	30,6
Iran	664,8	1789,8	4366,2	8175,5	169,2	143,9	87,2	133,5
Jordan	230,3	250,7	344,1	341,8	8,9	37,3	-0,7	15,1
Lithuania	273,9	307,9	457,5	457,4	12,4	48,6	0	20,3
Malaysia	471,4	479,3	808,1	2092,2	1,7	68,6	158,9	76,4
Morocco	437,8	400,3	378,6	385,8	-8,6	-5,4	1,9	-4
Mexico	2883,5	3658,5	4223,6	4172,8	26,9	15,4	-1,2	13,7
Nigeria	416,5	357,8	427,9	439,3	-14,1	19,6	2,7	2,7
Pakistan	295,9	359,7	741,2	1267,9	21,6	106,1	71,1	66,2
Poland	5100,2	6581,8	7137,5	7567,2	29	8,4	6	14,5
Romania	917,2	874,9	1252,3	1625,9	-4,6	43,1	29,8	22,8
Russia	17145,4	15147,8	13953,7	14150,9	-11,7	-7,9	1,4	-6
Saudi Arabia	604,9	549,3	589,2	1491,2	-9,2	7,3	153,1	50,4
South Africa	2302,5	2204,8	2808	3124,6	-4,2	27,4	11,3	11,5
Thailand	549,5	1018,6	1727,7	2304	85,4	69,6	33,4	62,8
Tunisia	256,8	436,1	758,1	1015,5	69,8	73,8	34	59,2
Turkey	3222,7	6038,8	8640,7	8328,4	87,4	43,1	-3,6	42,3
Ukraine	2354,9	1993,4	1846,9	1726,9	-15,4	-7,3	-6,5	-9,7
Venezuela	498	576,8	497,7	302,1	15,8	-13,7	-39,3	-12,4

Source : NSF 2014

In terms of absolute number of scientific publications in 1999, we can distinguish four groups of countries (see Fig. 5). Russia and China have the highest number of publications (17145,4 and 15714,7 respectively), followed by India (10190,4 publications). Brazil and Poland are the third group with 5859,3 and 5100,2 scientific articles respectively. Other countries form the fourth group having a small number of publications. Thus, we find that the bloc of BRIC (Brazil, Russia, India and China) is the most efficient in terms of scientific power.

In 2011, we distinguish three groups only. The first consists of China that excels against its partners with 89894,4 scientific publications. The second group consists of India, Brazil and Russia. It is characterized by mid-level scientific articles. The third group consists of countries with low scientific power (see Fig. 6).

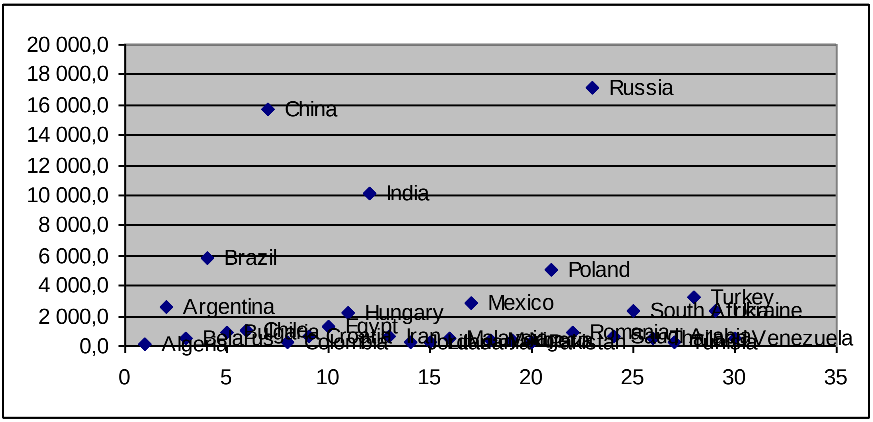

Figure 5: Scientific publications in 30 DC for 1999

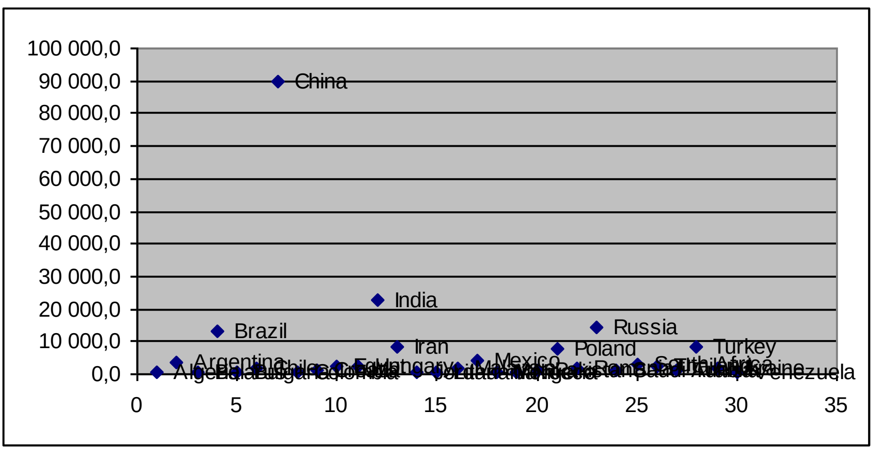

Figure 6: Scientific publications in 30 DC for 2011

Table 7 describes the scientific publications by comparing 30 DC observed with developed countries.

Vol. VI, Issue 3
June 2016

Table 7: Scientific publications: Comparison developing / developed countries

	Number of scientific publications				Change	Change	Change	Change
Country	1999	2003	2007	2011	1999 - 2003 (%)	2003-2007 (%)	2007-2011 (%)	1999-2011 (%)
30 DC total	77794,1	101575,3	147832,5	195617,4	30,6	45,5	32,3	36,1
World total	610203	661789,6	758603	827704,9	8,5	14,6	9,1	10,7
United States	188004,1	196463,7	209916,4	212394,2	4,5	6,8	1,2	4,2
Japan	55273,8	57231,2	52910,6	47105,7	3,5	-7,5	-11	-5
United kingdom	46787,9	45232,1	47139,7	46035,4	-3,3	4,2	-2,3	-0,5
As share of total world publications (%)								
30 DC	12,7	15,3	19,5	23,6	20,4	27	21,3	22,9
United States	30,8	29,7	27,7	25,7	-3,6	-6,8	-7,3	-5,9
Japan	9,1	8,6	7	5,7	-4, 5	-19,3	-18,4	-14,1
UK	7,7	6,8	6,2	5,6	-10,9	-9,1	-10,5	-10,1

Source : NSF 2014

From the table above, we note that for the period 1999-2011, the total number of scientific publications in the world is growing by 10,7% on average (The leading players in the total scientific publications are the United States, Japan and the United Kingdom. They are chosen on the basis of the sum of scientific publications during the period 1999-2011).

The mean change for the 30 countries surveyed was 36.1%. Developing countries increase their share of world scientific publications from 13% in 1999 to 24% in 2011. This is a slight increase. In 2011, the share of all DC observed is not even that of the United States whose share is 26%. We conclude that developing countries have poor scientific performance.

Conclusions

The objective of this paper was to understand the technological innovation in the context of developing countries. We presented some statistics describing innovation activity in DC. We found that DC have made progress in terms of innovation, but are still far from world leaders. We found also that the BRIC countries, namely, India and China, are the most efficient in terms of scientific and technological power.

References

[1]. Solow, R.M. (1956). A Contribution to the theory of economic growth. *The Quarterly Journal of Economics* 70 (1): 65-94.

[2]. Romer, P. (1986). Increasing returns and long run growth. *Journal of Political Economy* 94: 1002-1037.

[3]. Abramovitz, M. (1986). Catching-up, forging ahead and falling behind. *Journal of Economic History* 46: 385-406.

[4]. Freeman, C. (1987). Technology Policy and Economic Performance: Lessons from Japan. London: Pinter.

[5]. Romer, P. (1990). Endogenous technological change. *Journal of Political Economy* 98: 71-102.

[6]. Aghion, P., Howitt, P. (1992). A model of growth through creative destruction. *Econometrica* 60: 223-351.

[7]. Grossman, G.M., Helpman, E. (1991). Quality ladders in the theory of growth. *Review of Economic Studies* 58: 86-91.

[8]. Jones, C. I. (1995). Time series test of endogenous growth models. *Quarterly Journal of Economics* 110: 495-525.

[9]. Taillant, P. (2005). *L'analyse évolutionniste des innovations technologiques: l'exemple des energies solaire photovoltaique et éolienne*. Thèse de doctorat, Université de Montpellier I.

[10]. Grilliches, Z. (1990). Patent statistics as economic indicators: A survey. *Journal of Economic Literature* XXVIII: 1661-1707.

[11]. Eaton, J., Kortum, S. (1996). Measuring technology diffusion and the international sources of growth. *Eastern Economic Journal* 22 (4): 401-410.

[12]. Kanwar, S., Evenson, R.E. (2003). Does intellectual property protection spur technological change? *Oxford Economic Papers* 55 (2): 235-264.

[13]. Furman, J.L., Porter, M.E., Stern, S. (2002). The determinants of national innovative capacity. *Research Policy* 31: 899-933.

[14]. Hall, B.H., Jaffe, A.B., Trajtenberg, M. (2001). *The NBER patent citations data file: Lessons, insights and methodological tools*. NBER Working Paper 8498 http://www.nber.org/papers/w8498

[15]. Acs, Z.J., Anselin, L., Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy* 31: 1069-1085.

[16]. Grasjo, U. (2004). *The Importance of accessibility to R&D on patent production in Swedish municipalities*. CESIS Working Paper 19 https://static.sys.kth.se/itm/wp/cesis/cesiswp19.pdf

[17]. Schubert, A. Telcs, A. (1986). Publication potential - An indicator of scientific strength for cross-national comparisons. *Scientometrics* 9 (5-6): 231-238.

[18]. Galvez, A., Maqueda, M., Martinez-Bueno, M., Valdivia, E. (2000). What can the volume and authorship of scientific articles tell us about scientific progress in various regions? *American Scientist* 88: 526-533.

[19]. Gaillard, J. (2010). Measuring research and development in developing countries: Main characteristics and implications for the Frascati Manual. *Science, Technology & Society* 15 (1): 77–111.

[20]. Wang, E.C. (2007). R&D efficiency and economic performance. A cross-country analysis using the stochastic frontier approach. *Journal of Policy Modeling* 29: 345-360.

[21]. Amsden, A.H., Mourshed, M. (1997). Scientific publications, patents and technological capabilities in late-industrializing countries. *Technology Analysis & Strategic Management* 9 (3): 343-360.