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A New Proposal for Innovation Indicators: A Study of the World's Largest Patent Producing Countries

Giuliano Carlo Rainatto[1], Orlando Roque Silva[2], Norberto Almeida de Andrade[3], Evandro de Almeida[4], Pedro Dornas Cipriani[5], Thiago Saboya[6], Rodrigo Teixeira Conceição[7] & Wellington Fernando Bastos[8]

1 Msc in Business administration, Anhanguera University, Brazil

[2] Doctor in Engineering, FMU University, Brazil

[3] Msc in Business & Managment,USCS University Brazil

[4] PUC-SP University, Brazil

[5] Msc in Business Administration, FMU University, Brazil

[6] Msc in Business and Management, FAM University, Brazil

[7] Coordinator of High School, Brazil

[8] Msc in Business and Management, UNIP University, Brazil

Correspondence: Giuliano Carlo Rainatto, Msc in Business administration, Anhanguera University, Brazil. E-mail: giulianorainatto@yahoo.com.br

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Abstract

Innovation has become an eloquent topic among researchers and the market, but it is important to understand where we are innovating and at what costs and how efficiently this has been done. Promoting innovation performance index based on patent production, R&D investment and the number of researchers being a tool to assist managers in measuring how the resource is used. According to the analysis made using the countries in the list of the top 10(ten) patent applicants, we have identified that the first place is not the most efficient in employing researchers by a patent granted or in the efficiency of the resource employed vs. the granting of patents. This study shows that much of the resource that has been employed with researchers and research has a low return for the country. The money invested by Rep. Korea, showed the best efficiency in volume of researchers producing innovation, and China presents the best numbers in volume of production, and money by patent applied. Research has shown that eastern countries are at the forefront of researcher performance index and dressed in the production of a patent, bringing efficiency to the resources employed.

Keywords: patent, indicators, performance, management

1. Introduction

Performance index exists since the early days of accounting created by Frei Luca Pacioli in the mid-1450s (Silva & Cavalcanti, 2004), the focus of adjusting and reflecting the performance of a company by number has been instrumental in creating a system. Modern management systems based on performance and optimization of the resources applied in a given system.

Innovation is embedded in companies as vitally important (Marc, Marston, & Roth, 2018) for business continuity, but there is a management gap between how much we can invest in innovation and how it is performing and performing. Researchers or collaborators work to produce innovation. Optimizing Resources (Pagar, 2017) is described as a way to adjust processes and their methods with the resources available to their collaborators or managers.

The introduction of the innovation management index approached as a factor of facilitation and control by managers not only of companies but of countries to the point of understanding how their country's scientific - economic production is based on the investment that is being made over the years of time. This tool in line with economic figures extracted from World Bank reports becomes a tool for managing investment and where to allocate resources compared to other countries.

As a country's research structure grows, it must be measured based on its productions, and a point of production measure that generates competitive advantage (Porter, 1985) is the patent, which guarantees its holder an exclusivity limited to time to explore your innovation. And patent also gives a way for managers to understand what has been produced of innovation with investments applied in the country.

2. Methodology

This article represents a manner of represents the rate of the innovation, compressed in a group of indicators based on-premises developed by the researchers, the exploratory method had been used collect the data about the researchers per million, the rate of investment in R&D (research and development) and as to base all the calculus we used the total patents deposits and the total patent grants made only by local researchers and companies.

The exploratory method presented (GIL, 2007) defines and recommend the research need to have, bibliographical knowledge and examples that stimulate comprehension. The example used had been retrieved from de Balanced Score Card system (Gibbons & Kaplan, 2015), who was used to measure and control the immeasurable.

The research is primarily based on the 10 biggest patentees appointed on the WIPO 2019 Intellectual Property indicators, in order: China, United States of America "U.S", Japan, Republic of Korea, Germany, Russian Federation, France, United kingdom "U.K", India (Note 1), Italy, and all of this data has been collected from the WIPO database for researchers.

To understand about the creation of the indicators, the use of Quantitative Indicators that can reflect the output about the activities according to a plan executed by governments and companies that could invest in innovation as a way of living. The Methodology created by George T. Doran (Doran, 1981), that introduces the specification in each letter that the manager could control a specify his order of greatness.

Table 1. The smart proposal

Letter	Definition	Use
S	Specific	Target a specific area for improvement
M	Measurable	quantify or at least suggest an indicator of progress
A	Assignable	specify who will do it
R	Realistsic	state what results can realistically be achieved given available resources
T	Time Related	specify when the result(s) can be achived

Source: Adaptation from the authors (Doran, 1981).

Based on the model, the letter "M" has been chosen to create the indicators based on simple mathematics, using Split or a fraction to understand the evolution of innovation production based on patent productions of the residents from the countries. Our formula is based on mathematical principles.

$$g = \frac{\Delta y}{\Delta x} . t$$

g = Indicator of efficiency

Δy = Variation of the value money spended selected trough time

Δx = Variation of the patent production selected trought time (WORLDBANK, 2019) (MUNDI, 2019). $t = time\ measured.$

And the simple mode to create a visualization of the rate of efficiency, is spliting the economic number selected with the patent production of the same year.

$$g = \frac{x}{y}$$

g = Indicator of efficiency.

x = Economic value selected.

y = Patent Volume produciton selected.

To reach the results, an analysis measuring the numbers achieved with all the tables compressed, will indicate

which country has the best efficiency in money spenditure on innovation. The growth of total efficiency and productivity (Hulten, 2010) will show the results in productivity, without assumes all the innovations that not had been patented.

All the data of the research has been retrieved from de World intelectual property organization website, and all the calculations has been made using the Microsoft® Excell software were all the tables are available to compare and understand the results achieved. All the patents numbers has been retrieved from the WIPO database (WIPO, 2019).

3. Results

To start, we need to understand the premises that guided the research. The first one is the comprehension of the numbers of researchers per million in each country studied, this number allows us to see how many is our sample of researchers engaged in each level of study in different areas like basic research, that is focused on understandings of nature areas of physics and chemistry. This area does not generate several numbers of patents because is oriented to investigate the mysteries of the universe.

And we have several researchers based on the applied fields, and that fields generate the patents and provide new products to the markets normally based on the basic research. All the indicators use d with the patent production is in the function of the resident application patents and patents granted only.

The First Indicator proposed to show the efficiency of the researchers on producing patents, and granting them, generating innovation to the areas of applications they are inserted. This indicator is made using the number of patents granted in every field on the WIPO Databases split by the number of researchers per million of habitants multiplied by the number of habitants in the country. Here we can create a rate of innovation per researcher in each country and visualize in an easy way how fast and productive are researchers are going.

$$\text{Indicator 1 - } \frac{Number\ of\ patents\ Granted}{Researchers\ per\ milliox\ x\ Number\ of\ million\ habitants}$$

Table 2. Efficiency by researchers generating innovation

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017
China	0,0576	0,0670	0,0863	0,1038	0,0978	0,1078	0,1648	0,1807	0,2110
France	0,0381	0,0349	0,0343	0,0427	0,0373	0,0376	0,0385	0,0384	0,0365
Germany	0,0319	0,0289	0,0243	0,0231	0,0276	0,0301	0,0266	0,0265	0,0278
Índia	0,0094	0,0056	0,0036	0,0032	0,0025	0,0026	0,0028	0,0036	0,0051
Italy	0,1617	0,1408	0,0539	0,0439	0,0598	0,0569	0,0493	0,0440	0,0374
Japan	0,2425	0,2731	0,2847	0,3243	0,3125	0,2368	0,1983	0,2136	0,2104
Korea, Rep.	0,1721	0,1938	0,2483	0,2642	0,2949	0,2786	0,2111	0,2246	0,2595
Russian Federation	0,0595	0,0489	0,0455	0,0507	0,0485	0,0517	0,0500	0,0488	0,0509
United Kingdom	0,0077	0,0084	0,0108	0,0108	0,0086	0,0080	0,0095	0,0095	0,0110
United States	0,0641	0,0873	0,0837	0,0917	0,0971	0,1011	0,0959	0,1004	0,1035

Source : Research from authors.

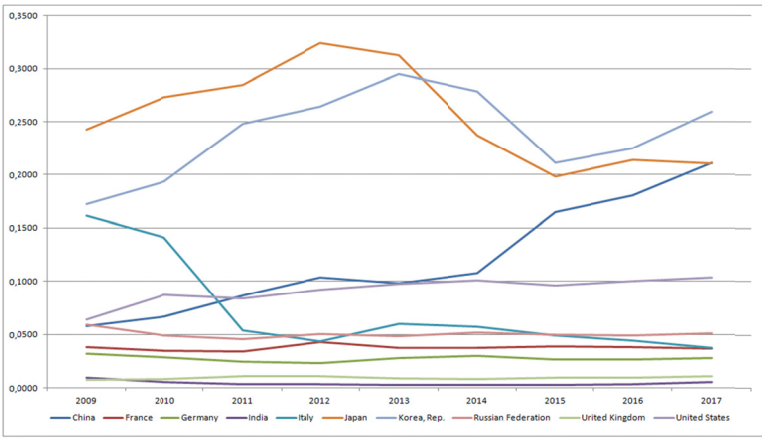

Figure 1. Efficiency by researchers generating innovation

The second proposed indicator is based on the number of applications to patent protection. This number is normally huge and it is used to show the greatness of a country producing innovation, but an application its only used to set who was the first inventor to reach that specific invention.

The number of researchers is used to create a rate of patent requests and provides an indicator that shows the volume of innovation without any warranty of exclusivity guaranty by the protection of a patent.

$$\text{Indicator 2} = \frac{Number\ of\ Patent\ applications}{Researchers\ per\ milliox\ x\ Number\ of\ million\ habitants}$$

Table 3. Efficiency of researchers in patents applications

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017
China	0,2014	0,2451	0,3192	0,3867	0,4819	0,5335	0,6073	0,7222	0,8083
France	0,0583	0,0587	0,0570	0,0544	0,0536	0,0516	0,0499	0,0513	0,0516
Germany	0,1459	0,1392	0,1378	0,1307	0,1317	0,1353	0,1198	0,1174	0,1247
India	0,0384	0,0446	0,0428	0,0438	0,0466	0,0455	0,0440	0,0440	0,0470
Italy	0,0873	0,0865	0,0834	0,0765	0,0708	0,0713	0,0000[a]	0,0685	0,0712
Japan	0,4325	0,4225	0,4159	0,4190	0,3847	0,3618	0,3612	0,3600	0,3598
Republic of Korea	0,5210	0,4977	0,4747	0,4657	0,4923	0,4690	0,4629	0,4452	0,4554
Russian Federation	0,0579	0,0650	0,0592	0,0647	0,0651	0,0539	0,0649	0,0621	0,0551
United Kingdom	0,0614	0,0597	0,0603	0,0593	0,0549	0,0540	0,0514	0,0467	0,0461
United States of America	0,1699	0,1897	0,1845	0,1979	0,2025	0,1926	0,1881	0,1972	0,1919

Source: Authors research.

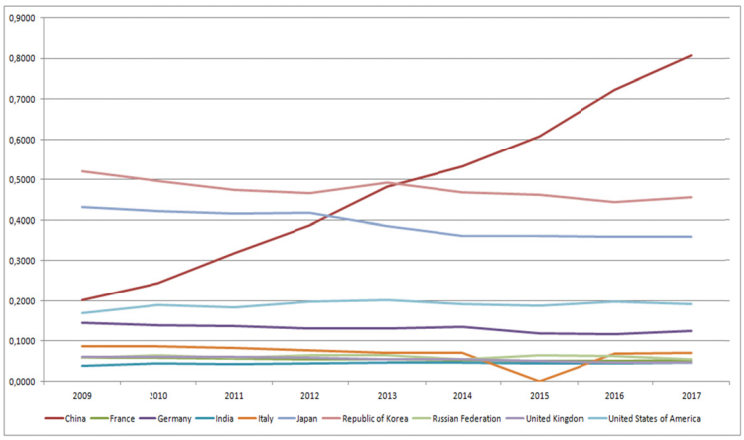

Figure 2. Efficiency of researchers in patents applications

The third Indicator is based on how much the country invest in R&D (Research and Development), and the volume of the patents applications requested. This indicator will provide an overview of the cost of the production of an Innovation that could be patent as unique in the world.

$$\text{Indicator 3} = \frac{Expenditure\ in\ USD\ in\ R\&D\ in\ country}{Number\ of\ patent\ applications}$$

Table 4. Expenditure in USD per patent application

Country	2009	2010	2011	2012	2013	2014	2015	2016	2017
China	$371.169,5	$356.511,9	$324.197,4	$304.942,3	$271.321,4	$264.358,1	$234.709,6	$195.618,3	$207.598,2
France	$4.220.539,0	$3.903.654,7	$4.279.147,6	$4.110.774,9	$4.280.779,6	$4.476.759,4	$3.863.756,8	$3.910.723,4	$3.926.847,8
Germany	$1.989.365,9	$2.009.637,0	$2.269.115,4	$2.224.981,7	$2.285.806,7	$2.367.894,0	$2.122.884,0	$2.171.862,6	$2.398.413,8
India	$1.606.611,1	$1.596.631,5	$1.756.997,4	$1.610.426,7	$1.415.049,7	$1.246.114,2	$1.047.434,7	$1.245.276,6	$1.416.558,8
Italy	$3.027.738,5	$2.927.993,7	$3.131.623,4	$3.121.565,1	$3.353.799,1	$3.359.840,4		$2.716.046,4	$3.063.635,5
Japan	$598.694,9	$647.520,4	$735.399,0	$739.659,6	$677.163,4	$672.221,1	$605.566,3	$649.700,6	$659.296,1
Korea, Rep.	$233.903,1	$288.562,3	$326.979,2	$333.287,7	$340.119,9	$370.919,2	$350.479,9	$368.521,9	$440.601,6
Russian Federation	$599.222,1	$600.970,0	$785.219,3	$792.215,8	$821.109,9	$919.116,8	$512.335,8	$526.039,2	$769.730,4
United Kingdom	$2.592.802,6	$2.693.782,4	$2.937.771,0	$2.847.204,6	$3.113.777,5	$3.405.341,0	$3.333.272,5	$3.305.879,2	$3.414.647,5
United States	$1.911.166,4	$1.802.714,3	$1.858.460,0	$1.737.596,1	$1.726.402,2	$1.835.492,0	$1.918.313,4	$1.939.508,9	$2.091.797,6

Source: Authors research.

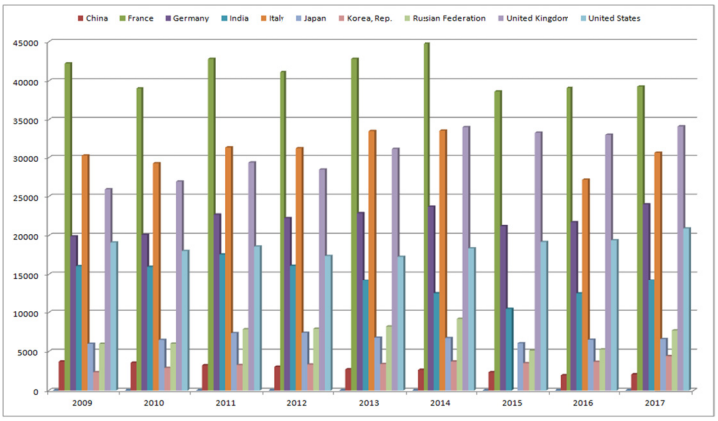

Figure 3. Expenditure in USD per patent application

And the fourth indicator uses the same methodology as the third but instead of uses, the Number of applications of the patents uses the patents granted. This indicator shows how much cost a patent in each country studied and the efficiency in produces innovation based on the expenditure in USD in R&D in the country

$$\text{Indicator 4} = \frac{Expenditure\ in\ USD\ in\ R\&D\ in\ country}{Number\ of\ patents\ Granted}$$

Table 5. Efficiency based on money expenditure

Country Name	2009	2010	2011	2012	2013	2014	2015	2016	2017
China	$1.296.751,94	$1.304.886,25	$1.199.418,34	$1.136.084,84	$1.337.287,34	$1.308.467,43	$ 864.956,50	$ 781.940,90	$ 795.430,75
France	$6.448.807,98	$6.557.819,67	$7.114.113,17	$5.235.233,99	$6.144.079,34	$6.141.249,86	$5.005.424,66	$5.229.759,59	$5.540.868,39
Germany	$9.105.907,32	$9.690.528,79	$12.886.526,58	$12.561.303,22	$10.893.216,94	$10.640.900,99	$9.570.486,74	$9.620.747,51	$10.746.760,79
India	$6.568.943,79	$12.731.733,98	$21.164.947,66	$22.334.769,66	$26.860.356,19	$21.815.330,78	$16.382.615,04	$15.414.282,21	$12.967.298,58
Italy	$1.635.301,63	$1.798.242,69	$4.848.502,82	$5.437.128,52	$3.970.358,97	$4.210.693,22	$3.880.216,55	$4.229.422,49	$5.837.522,42
Japan	$1.067.768,03	$1.001.751,43	$1.074.319,00	$ 955.647,11	$ 833.715,25	$1.026.986,14	$1.103.053,22	$1.094.717,70	$1.127.471,23
Korea, Rep.	$ 708.088,17	$ 741.230,42	$ 625.198,61	$ 587.356,62	$ 567.691,17	$ 624.435,87	$ 768.398,22	$ 730.405,65	$ 773.107,83
Russian Federation	$ 582.972,59	$ 798.305,49	$1.023.163,35	$1.011.175,58	$1.102.784,96	$ 957.523,09	$ 664.820,44	$ 670.090,50	$ 832.805,04
United Kingdom	$20.660.403,51	$19.090.172,16	$16.329.527,14	$15.648.718,40	$19.933.100,83	$22.976.764,37	$18.076.449,69	$16.285.981,72	$14.349.305,50
United States	$5.064.052,69	$3.919.288,82	$4.097.148,46	$3.748.277,40	$3.600.381,33	$3.498.028,66	$3.762.780,42	$3.810.562,04	$3.880.172,31

Source: Authors Research.

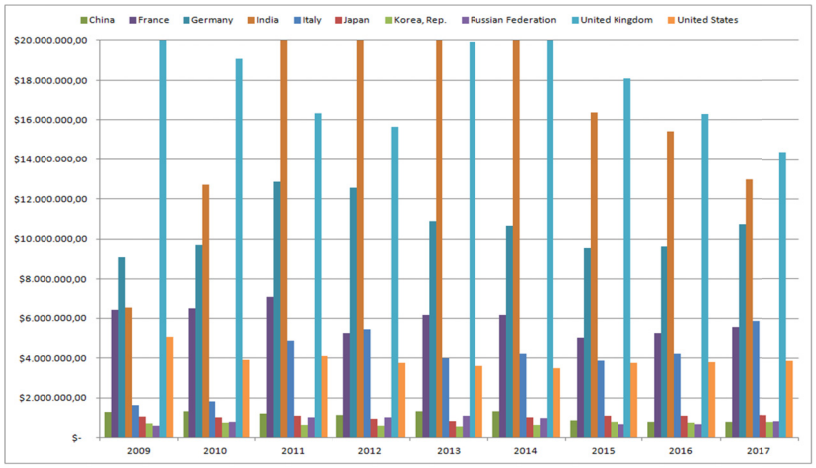

Figure 4. Efficiency based on money expenditure

4. Discussion

Patens are important tools to measure innovation in any country, and it's an administrative title provided by the state in a administrative way. (Rainatto, Silva, de Andrade, Paschoal, & Silva, 2019). This tool had been used for centuries to accelerate technology in economy, and helps to increase the rate of GDP measured Anually (Chaaban & Cunningham, 2011). The importance to measure the performance spenditure had been described by (Ye, 2017) is to show to the contributors the importance of the tax payment, and the correct application of the resources made by the managers, and show in a quickly way to all the responsible, who have the commitment to do a fast act to correct the course of the investment.

Performance indicators are being used since the 1990s (Gibbons & Kaplan, 2015), with the implementation of the BSC (balanced Scorecard) system in the world of management and business. There are two forms to measure an firm or an efficiency based on production, the informal that type is beyond the agency control with the executives giving adjustments all the time with a lot of adaptation, and adjustments that can be measured and the formal that has an manner to understand about all the information that the companies or the countries has and format to an indicator system.

Kaplan and Norton (1992) gives an overview of the creation of the informative based on indicators, representing the customer experience and measuring "works" inside the firms that can be measured normally. This evolution of understanding drives to the creation of a bunch of economic indicators and had been used since the comprehension of the importance of this KPI (Key performance indicators).

Innovation is not so far away from all the quality measurement proposed by Kaplan and Norton, and the great opportunity to create value in quality issues to secure the costumers of a company that provides creations and understand the meaning of delivering innovation as a KEY-FACTOR to assure perpetuity on the relations (Liping, Huiyang, Zuogong, & Yunlong, 2019).

The importance of innovation in countries is based on the same premises that had been used for years in regular business, create a relationship based on products that can be sell with higher value and can change the environment where the company is inserted (Sangiovanni-Vicentelli, 2005), so we can understand that the innovation had to be measured as an important factor of country evolution based on the money invested on research, and the volume of researchers focused to create and develop products to the society.

Knowing the model of SCP (Structure, conduct, and performance), (Lopes, 2016) is obligatory to economists connected to analyze and observe how the strategy of countries and companies are developed to the users and workers to arrange a new model and correlate industrial concentrations and performance, being used as a reference to comprehended competition between then. The structure imports on the differentiation of the products made and on the introduction of the Innovation on the market, bringing investments, technology and creating know-how to the countries evolved.

The fact of the conduct in the companies affects the strategy, (Kupfer, 1992) can modify the sizes and the power against the competition between firms and companies creating a GAP o technology that can be settled and used to produce new products and guaranty the prosperity of the nations. Innovation is a tool to empower the

companies to provide resources to the countries, but we have to analyze how much we invest in R&D, how many researchers are involved and how many products or patents are granted with all the investments made in these areas.

Indicators as propose in this study came to explain the differences between efficiency and productivity, using two different ways to understand and provide the creation of these new terms to reach a new level of management innovation using the government's money. The actual means for measure innovation is based on the OSLO Manual (EUROSTAT, 2018), including all the definitions and measurements for all the types of innovation. But to define and measure innovation in which countries are investing money from the contributors is important to create data about the rate and the efficiency of all the researches using data available to all the citizens.

If we look at the results of the indicators, we can analyze which country invest better, and which country has the best team of researchers based only in a few numbers. China has the best total number of the patent application, but don't have the best production indicator based on the number of researchers, the USA has the major amount of money invested but doesn't have the major numbers in total applications, total patents granted even efficiency stay behind other countries.

The WIPO has a Scale that put all the countries and their volumes of patenting, we gave that number at the beginning of this article, but we have to introduce a new way to compare who spend better the money and has the best researchers. If we can comprehend that we can lean with the results and improve de production o innovation with less Expenditure, not only in money but in time and resources too.

Table 6. Resume of indicators (2017)

Country	1 - Efficiency by researchers generating innovation	2 - Efficiency of researchers in patents applications	3 - Expenditure in USD per patent application	4 - Efficiency based on money Expenditure
China	0,21	**0,81**	**$ 207.598,22**	$ 795.430,75
France	0,04	0,05	$ 3.926.847,83	$ 5.540.868,39
Germany	0,03	0,12	$ 2.398.413,78	$ 10.746.760,79
India	0,01	0,05	$ 1.416.558,81	$ 12.967.298,58
Italy	0,04	0,07	$ 3.063.635,51	$ 5.837.522,42
Japan	0,21	0,36	$ 659.296,08	$ 1.127.471,23
Korea, Rep.	**0,26**	0,46	$ 440.601,58	**$ 773.107,83**
Russian Federation	0,05	0,06	$ 769.730,42	$ 832.805,04
United Kingdom	0,01	0,05	$ 3.414.647,54	$ 14.349.305,50
United States	0,10	0,19	$ 2.091.797,64	$ 3.880.172,31

As we can see in table 5, the countries that invest more money on the R&D area (USA and CHINA), does not have the best efficiency and the best number, China has the biggest to numbers when involve the total number, because they produce a lot of patent applications, and when they as used splitting other numbers they create great results, instead of Korea Republic, has minor numbers but the conversion efficiency rate in patents of innovation products is higher and with less money per patent of innovation.

Table 7. Resume of indicators (2009)

Country	1 - Efficiency by researchers generating innovation	2 - Efficiency of researchers in patents applications	3 - Expenditure in USD per patent application	4 - Efficiency based on money Expenditure
China	0,06	0,20	$ 371.169,53	$ 1.296.751,94
France	0,04	0,06	$ 4.220.539,01	$ 6.448.807,98
Germany	0,03	0,15	$ 1.989.365,89	$ 9.105.907,32
India	0,01	0,04	$ 1.606.611,09	$ 6.568.943,79
Italy	0,16	0,09	$ 3.027.738,51	$ 1.635.301,63
Japan	0,24	0,43	$ 598.694,92	$ 1.067.768,03
Korea, Rep.	0,17	0,52	$ 233.903,07	$ 708.088,17
Russian Federation	0,06	0,06	$ 599.222,06	$ 582.972,59
United Kingdom	0,01	0,06	$ 2.592.802,59	$ 20.660.403,51
United States	0,06	0,17	$ 1.911.166,40	$ 5.064.052,69

When we Compare a historical series we can see the changes that reflects in the future of innovation, Japan in 2009 has the best rate of researchers producing innovation (patents granted), when the Republic of Korea has the best rates investing the money on applications that will be transformed in patents years ago, and Russia had the best number in comparison of efficiency of the money invested producing patents with less money than the other.

5. Conclusions

Innovation management is currently in question, tools have been sought to measure advances in research and development that bring resources and differentiate countries in the world market. The road to an extremely agile market is innovation followed by its main patent control tool. The composition of indicators for more agile monitoring assists in creating value in how long-term investment and follow-up of innovative processes help managers improve their resource allocation decisions at both the micro and macro levels.

The proposal to create economic indicators portrays a way of understanding the past to study the future, translating into numbers and comparing what was done in each moment of the country's economy, and how the resources and work of the researchers were allocated. These numbers are an important tool and highlight what has been much addressed about efficiency, investment and the growth of the eastern market against western competitors.

When comparing the rates and the results of the proposed index we can see that in the 10-year historical analysis, CHINA, JAPAN, and KOREA REP, have always been ahead of the world competitors, and now reap the fruits of the investments made over the years. The work had the limiting factors of data specifically oriented to an analysis in front of researchers and their numbers and is guided by a further study on the separation between researchers from basic science and applied science.

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Note

Note 1. The numbers of India was not been extracted from the WORLD BANK DATA, we use a local source to find it (PTI, 2019).