SCIENTIFIC ARTICLE

BRAZILIAN NATIONAL INNOVATION SYSTEM: AN ANALYSIS BASED ON THE GLOBAL INNOVATION INDEX

SISTEMA NACIONAL DE INOVAÇÃO DO BRASIL: UMA ANÁLISE BASEADA NO ÍNDICE GLOBAL DE INOVAÇÃO[1]

SISTEMA NACIONAL DE INNOVACIÓN EN BRASIL: UN ANÁLISIS BASADO EN EL ÍNDICE GLOBAL DE INNOVACIÓN[2]

Juraci Ferreira Galdino

ABSTRACT

Development and defense strategies are inseparable, and their driving forces are innovation.In a globalized world in which new, challenging, asymmetric threats add up to the old, traditional, and increasingly dangerous threats, innovation becomes critical to promoting economic growth, technological capacity building and autonomy in sensitive areas. With weak innovation indicators, Brazil ranks 69th in the international ranking of the Global Innovation Index and 99th in the international ranking of the Innovation Efficiency Rate. Using as a reference the data of the Global Innovation Index, this work aims to analyze the evolution of the Global Index and the Innovation Efficiency Ratio from 2013 to 2017, to conclude on the world and Brazilian trends of the National Innovation System. The results show that the world is less innovative and more unequal. In the national context, they indicate deterioration of the indices of innovation and distancing of developed countries: Brazil is staying behind.

Keywords: *Innovation. Innovation Inputs. Innovation Products. Global Innovation Index. Triple Propeller.*

RESUMEN

Las estrategias de desarrollo y de defensa están indisolublemente ligadas, y sus muelles propulsores son la innovación. En un mundo globalizado en el que abundan nuevas y desafiadoras amenazas asimétricas que se suman a las antiguas, tradicionales y cada vez más peligrosas, la innovación es fundamental para promover el crecimiento económico, la acumulación de capacidad tecnológica y la autonomía en áreas sensibles. Con indicadores de innovación mediocres, Brasil ocupa la 69ª posición en el ranking internacional del Índice Global de Innovación y la 99ª clasificación en el ranking internacional de la Tasa de Eficiencia de Innovación. Utilizando como referencia los datos del Global Innovation Index, el objetivo de este estudio es analizar la evolución del Índice Global y la Tasa de Eficiencia de la Innovación en el período de 2013 a 2017, para concluir sobre tendencias mundiales y brasileñas del Sistema Nacional de Innovación. Los resultados muestran que el mundo está menos innovador y más desigual. En el contexto nacional, indican el deterioro de los índices de innovación y el distanciamiento de los países desarrollados: Brasil se está quedando atrás.

Palabras clave: *Innovación. Insumos de Innovación. Productos de Innovación. Índice Global de Innovación. Triple Hélice.*

RESUMO

Estratégias de desenvolvimento e de defesa são indissociáveis, e suas molas propulsoras são a inovação. Em um mundo globalizado no qual pululam novas e desafiadoras ameaças assimétricas que se somam às antigas, tradicionais e cada vez mais perigosas, a inovação se torna fundamental para promover o crescimento econômico, o acúmulo da capacidade tecnológica e a autonomia em áreas sensíveis. Com indicadores de inovação pífios, o Brasil se encontra na 69ª posição no ranking internacional do Índice Global de Inovação e na 99º classificação no ranking internacional da Taxa de Eficiência de Inovação. Utilizando como referência os dados do Global Innovation Index, este trabalho visa analisar a evolução do Índice Global e da Taxa de Eficiência de Inovação no período de 2013 a 2017, para concluir sobre tendências mundiais e brasileiras do Sistema Nacional de Inovação. Osresultados mostram que o mundo está menos inovador e mais desigual. No contexto nacional, eles indicam deterioração dos índices de inovação e distanciamento dos países desenvolvidos: o Brasil está ficando para trás.

Palavras-chave: *Inovação. Insumos de Inovação.Produtos de Inovação. Índice Global de Inovação. Hélice-Tríplice.*

1 *Artigo disponível em português: <http://portal.eceme.eb.mil.br/meiramattos/>*

2 *Artículo disponible en español: <http://portal.eceme.eb.mil.br/meiramattos/>*

1. INTRODUCTION

Man's ability to develop technologies, change the environment for his own benefit, and accumulate knowledge over successive generations has led to its survival and evolution on planet Earth.

Today, innovation is a central element of sovereignty, competitiveness and economic growth and development of a nation. Necessary and peremptory condition to reach the Permanent National Objectives, innovation is dependent on the capacity to generate knowledge and to apply it in the productive sector.

Scientific and technological development; the links between academia, firms and government; research and development (R & D) investments; scientific production and patent registrations, although important (ALBUQUERQUE, 1996), are not sufficient to promote and leverage a country's capacity for innovation. In Brazil, in spite of the implementation in the last twenty years of several policies aimed at encouraging Science, Technology and Innovation, the results observed are at least modest (NEGRI, 2017).

Many factors influence the innovation process. Institutional aspects, such as the political environment, regulatory environment, business environment and legal security, are considered by national and foreign investors and entrepreneurs in the decision-making process to expand or even start a productive activity in a given country.

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Infrastructure is also important, since the efficiency of spending and the quality of logistics activities, such as transportation and distribution of goods and services, depend to a great extent on the existence of good manners. The Information and Communication Technologies (ICT) infrastructure and the services provided by the government using such means are increasingly important in the innovation process. In addition, the availability of electricity and the country's policy on environmental issues may favor or hinder innovation.

The sophistication of the domestic market, particularly its scale, purchasing power and ease of financing and incentives for entrepreneurial corporate activities, directly impacts a country's capacity for innovation. Sophistication of business, availability of skilled labor, capacity for training and improvement of human resources and public safety, also affect innovation.

In short, innovation is a complex and multidisciplinary subject that transcends aspects related to Science and Technology. It comes directly or indirectly from several actors and factors that form the so-called National Innovation System (CIMOLI, 2014; GODIN, 2009; LUNDVALL, 2007).

The term "National Innovation System" (SNI) was coined by Freeman in the late 1980s to designate a "set of public and private institutions, whose activities and interactions contribute to the creation, advancement and diffusion of technological innovations. one country "(FREEMAN, 1995). For Albuquerque (1996), SNI is "an institutional construction, product of a planned and conscious action that drives technological progress in capitalist economies."Also according to the author's thinking, SNIs are institutional arrangements involving firms, networks of interaction between companies, government agencies, universities, research institutes and companies' laboratories, as well as the activity of scientists and engineers, which are articulated with the with the industrial and entrepreneurial sector and with the financial institutions, forming the circuit of the agents that are responsible for the generation, implementation and diffusion of the technological innovations (ALBUQUERQUE, 1996, p 57).The Defense area is highly demanding of science, technology and innovation. Because of this, both the White Defense Paper (BRAZIL, 2016a), when the National Defense Policy (BRAZIL, 2016) and the National Defense Strategy (BRAZIL, 2016) highlight the association, the bonding and the mutual dependence between Defense Strategy and Development Strategy, as well as the need for scientific and technological development to promote autonomy in important areas such as cybernetics, nuclear and space.

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The Brazilian Army's Science, Technology and Innovation System has undergone a transformation process in which, among others, it seeks to create an environment favorable to innovation, to strengthen Brazil's Defense Industrial Base and, in particular, to better integrate and cooperation between academia, government and firms (PELLANDA, 2013). An important step in this process is the consolidation of the System Defense, Industry and Innovation Academy (SISDIA) (SILVA, 2017), newly created and inspired by the Triple Helix model (AMBROS, 2017) and the creation of the Innovation Management Agency (AGITEC) of the Brazilian Army (FERREIRA, 2017, STEPS, MAGNO NETO, DIAS, 2017). However, despite the efforts made by the Brazilian Army, its Science, Technology and Innovation System interacts, depends and is conditioned to the SNI of Brazil. Therefore, the capacity of innovation of the one, depends viscerally of this system. Thus, assessing this system, as well as its trends, is important not only for national growth and development, but also to boost the Defense area.

There are several indicators with the purpose of evaluating an SNI, among them the ones produced by the Global Innovation Index (GII), which are used to carry out the studies and analyzes of this work.

Due to the evolution of the innovation concept, the indicators generated by the GII have been changing over time, through changes in calculation methodologies, as well as inclusion and suppression of variables. Despite improving the indicators, these modifications make it difficult to study the evolution of an NIS. In 2012, for example, the methodology of the GII changed a lot to reflect the importance of the interaction between the triple helixactors and environmental aspects (ETZKOWITZ, 2005; MORGADO, 2013). In addition, the variables used in the composition of the indicators are not always updated annually. In addition, there are uncertainties as to when and to what extent improvements in indicators translate into effective innovation (resources invested in R & D can generate innovations in the unpredictable future, the same improvement in infrastructure, education and other indicators, whose benefits for generating innovation are difficult to quantify and undefined over time, and may be short-, medium- and long-term).

In spite of theaforesaiddifficulties, it is fundamental to study the evolution of these indicators to adjust policies, identify bottlenecks and trends, and even define new policies and strategies to increase competitiveness and promote economic growth, thus creating better conditions for national development .

It is worth noting that in the last five years the structure of pillars and sub pillars of the GII has been maintained (DUTTA, LANVIN, 2013, DUTTA, LANVIN, WUNSCH-VINCENT, 2014, 2015, 2016, 2017), facilitating evolutionary analysis, which is why the study presented here comprises the time cut from 2013 to 2017.

It should be noted that, although important, few studies analyze the evolution of NIS indicators, particularly the GII. This paper intends to contribute to filling this gap, particularly with regard to Brazil. Specifically, the main objective of this work is to analyze the evolution of the main GII indicators from 2013 to 2017, specifically the Global Innovation Index and the Innovation Efficiency Rate, in order to conclude on the Brazilian and national trends in the National Innovation System.

2SNI AND SCIENTIFIC-TECHNOLOGICAL DEVELOPMENT OF DEFENSE INTEREST

Technology preceded science in many centuries, and even after its emergence, it produced its advances without dependence. However, with the accumulation of technological capacity, much more complex problems in the various fields of knowledge could be faced with more sophisticated tools,and utensils and new advances became increasingly dependent on scientific studies. In fact, the first tools manufactured by humanshad an empirical basis, however, with the passage of time, not only the major breakthroughs but also incremental innovations, as defined by Figueiredo (2015), particularly those with high added value, became entirely dependent on the science-based knowledge.

Based on criteria such as longevity, beneficiation for the human being, impact on society, scientific and / or technological exploration and representativeness in the sociocultural period, Amarante (2009) cataloged 101 technologies with the greatest human impacts. According to his study, all the technologies generated in the period of chipped stone (fire, clothing, stone instruments and archery) are empirical.Likewise, the 16 (sixteen) technologies cataloged as having been generated during the agricultural revolution are empirical. Also according to this study, the first science-based technology (the glasses, developed by Roger Bacon) only appeared in 1266. However, after this invention, few were produced in an empirical way and, after 1829, the year in which the locomotive was invented by Stephenson, all the technologies listed by this author are scientifically based.

The work of cataloging the most important technologies of humanity is Herculean. Amarante, despite having done a careful and meticulous work, may have included technologies to the detriment of others that may be more impacting due to an unavoidable degree of subjectivity in this classification. Nevertheless, this work clearly shows the increasing importance of scientific knowledge in the generation of technologies over time.

Other studies on the association between science and technology come to similar conclusions. Long (1984), for example, argues that technology has accompanied humans since the beginning, but that production was amateurish, not systemic, and spontaneous and depended on the bright ideas of notable and privileged people. According to the author, this situation remained so until the advent of the Industrial Revolution; however, Long emphasizes that, around 1830, science began to be applied in the production of technology, a trend that intensified from 1880 onwards with the work of Thomas Alva Edison.

Schwab (2016) highlights the five revolutionary periods that changed completely all sectors of existing societies in their historical moments. The first of them took place about 10,000 years ago, and the other, the so-called industrial revolutions, started inthe 18thCentury. The first industrial revolution occurred between 1760 and 1840. The second started in the late 19th century and continued until the mid-20th century. The third one occurred around 1960 and, finally, the fourth one appeared at the beginning of the 21st century and is still in progress. A comparison between these revolutions unveils some trends, the most evident of which is the increasingly strong relationship between Science, Technology,and Innovation.

In addition, with the accumulation of scientific-technological knowledge, even incremental innovations, especially in high-technology areas, have become increasingly difficult to obtain without the support and use of advances in the scientific sphere. As a result, over the course of the twentieth century, leading global firms such as XEROX, DuPont, Merck, IBM, GM, KODAK and AT & T had their sophisticated applied research and development laboratories (CHESBROUGH, 2012). Today, innovating in high technology sectors, such as in the Defense area, is practically impossible without the support of R & D activities.

According to Figueiredo (2015), the accumulation of technological capabilities, fundamental for innovation activities and for strengthening the competitiveness of companies, has been studied since the first Industrial Revolution in the eighteenth century by classical thinkers, but it was Joseph Schumpeter starting in 1911, who brought innovation to the center of the debate on the economic development of nations.

Since then, technological capacity has received contributions from different authors and today it is understood as a reservoir of resources involving technical and physical systems, organizational and institutional system, products and services and, above all, people's minds. However, according to Figueiredo (2015), since the 1990s, with the advent of the Knowledge and Learning Economy, the subject has been gaining more prominence.

Developing and emerging countries are still consolidating their NIS and have a very different reality from that of developed countries. In those, according to the author, innovative technological capabilities still have to be built, as they have predominantly imitative firms, in addition to the deficient supply of highly qualified and precarious technological infrastructure. Because of this, in order for them to compete globally, they must build their technological capacity faster and more intensively than those who have consolidated capabilities and operate at the frontier of knowledge.

This requires an efficient SNI. A model that has been pointed to create an environment or a system conducive to innovation is called Triple Helix (TH), whose essence lies in the cooperation or integration between government, universities and firms, as advocated by Etzkowitz (2005). Another is open innovation, as defined by Chesbrough (2012), as opposed to closed innovation in which firms use verticalized strategies, internally conducting the whole process of research, development, production, sale and technical assistance.

Because of diverse forces of erosion that have shaken the innovation closed down throughout the twentieth century, a model prevalent hitherto, open innovation, through patent acquisitions and sophisticated business models, enables firms to apply not only good ideas, generated internally, but also those produced externally in universities, research centers and startups, can also generate substantial resources through the sale of patents or the licensing of technologies that firms do not intend to market or exploit directly.

It must be reiterated that innovation is fundamental to improve productivity, increase competitiveness, promote economic growth and enable a country to enter the Global Value Chain. A country with an incipient and inefficient SNI, in an increasingly integrated and globalized world, becomes a market to be exploited by multinational and transnational companies, supplier of cheap labor and exporter of mineral resources and commodities. This establishes a vicious circle, compromising economic growth, development and sovereignty. There is an obstacle to national autonomy in sensitive areas, and in particular, Defense Product Research and Development (R & D) activities are difficult, limiting itself to the Industrial Defense Base (IDB).

In particular, the analyses carried out in this study show that the Brazilian SNI is inefficient, precarious and without evidence of consolidation in the short term. Undoubtedly, this hinders the strengthening of the national IDB, lengthens the cycles of R&D projects of interest to the Defense sector and increases the chances of failure of these projects; it also makes it more challenging to achieve autonomy in strategic areas. Besides, this can make mobilization in the industrial sector more inefficient.[3]

It should be mentioned that important successful R & D projects of the Brazilian Army, for example, benefited from specific situations, in which research institutes that operated in the civil market had high technological capacity in areas related

3 Bradar, currently a member of the Embraer Defense Group, came from Orbisat, a company that participated, through R & D contracts, in the development of radars in support of the CTEx.

to and important to the intended development. BRADAR, the Center for Research and Development in Telecommunications (CPqD Foundation) and SPECTRA are some of these institutions that supported research and development projects carried out by the Army Technological Center (CTEx), through several R & D contracts of the last 12 years.[4]

BRADAR has participated in the development of the SABER M60 family of sensors, SENTIR M20, and has participated in SABER M200 R & D. Recently, Embraer Defense signed an M60 Technology Licensing Agreement, which is owned by the Brazilian Army, becoming a company responsible for commercial exploitation of this PRODE (non-exclusive licensing). Thus, in addition to meeting internal demand of the Armed Forces (with the radars M60 and M20), this company is negotiating the export of the M60 radar to several countries. The CPqD Foundation has been acting with great success in the development of Defined Radio waveforms (SDR)

Waveforms of the Ministry of Defense, and is currently the only national institution which, together with CTEx, controls the whole cycle of specification, research and development of waveforms of tactical radios below the line of the Equator (military radios based on the SDR technology and that follows the *Software Communications Architecture*internal communication pattern) (CASTELLO BRANCO et al., 2015; PRADO FILHO, 2017). The company SPECTRA Technology participated in the development of the Esquilo (Portuguese for squirrel)Helicopter Simulator and Fennec (SHEFE).

However, other R&D projects geared to the Armed Forces took longer than expected, did not reach satisfactory results or were interrupted, with the loss of valuable knowledge. Possible causes are the unavailability of crucial national expertise (human resources and inputs) to support R&D activities, the difficulty of exploitation of dual technologies on the civilian market of low added value and other problems that hinder the ability to innovate on account of an inefficient SNI. Therefore, expanding the capacity of the national SNI, as well as contributing to national development and growth, may increase the chances of success of the R&D of PRODE. It should be highlighted that even in cases of success, development cycles probably would have been reduced if Brazil had a consolidated and efficient SNI, in which research and products generated for the civilian market that could be harnessed for the development of defense products could abound (FITZGERALD; SANDER; PARZIALE, 2016; LESKE, 2018).

4 Information on this subject can be obtained at: <http://www.eb.mil.br/web/noticias/communication-of-exercise/-/asset_publisher/MjaG93KcunQI/content/industria-defesa-in-signature-of-radar-licensing contract-m60>. Accessed on: Dec 15, 2017.

3. MEASURING THE CAPACITY OF THE SNI: THE GLOBAL INNOVATION INDEX

The choice of the GII indicators for the studies carried out here is due to the extent to which the subject is treated by this organization, going beyond the traditional indicators that capture investment information in R & D, patents and published articles, including in obtaining the measures other factors forming the so-called "innovation ecosystem", which include aspects that, in some way, facilitate innovation (inputs;the IGI 2016 report, for example, includes 128 countries that together account for 92.8% of the world's population and 97.9% of global GDP, so the reported data provide a fairly complete world innovation (DUTTA; LANVIN; WUNSCH-VINCENT, 2016); the vast experience of the organization in the theme, with a history of more than 10 years of generation and dissemination of measures; the availability of a large database on the Internet, which includes not only innovation indicators but also the "raw data" used to obtain the indicators (subscripts, pillars, sub-pillars and the order of 80 variables and indicators); the reliability of data and indexes, due to the adoption of strict criteria to include a country in the reports and procedures of treatment of outliers; and, mainly, by the acceptance of the indicators generated by the organization in question, becoming, over the years, a reference on innovation evaluation, serving as a source of consultation for investors and governments around the world.

The GIIhas publishedannual reports since 2007, in its official page on the internet, containing information about the capacity and efficiency of innovation in various countries. Since 2013, they have been published in partnership with the *Cornell University*, INSEAD,a business a leading business school in the world, and the United Nations World Intellectual Property Organization (WIPO). Since then, the calculation structure has been maintained, despite small changes in some variables and intermediate indicators. The stabilization of the architecture or the main structure of the indicators from 2013 onwards makes it possible to analyze the time evolution of the indicators published in the IGI reports from that year (DUTTA, LANVIN, 2013, DUTTA, LANVIN, WUNSCH-VINCENT, 2014 , 2015, 2016, 2017)

Composed of four hierarchical levels, the architecture adopted by the *Global Innovation Index* (GII) to evaluate the innovation processes of the world economies is illustrated in Figure 1. The first level contains the two main indicators produced by the GII: The Global Innovation Index (GII) and the Innovation Efficiency Ratio (IER). The second level includes the sub-indicesInputs for Innovation (II) and InnovationOutputs

(IP), which constitute the basis for calculating the main indices.

The GII is obtained by the arithmetic average between II and IP, while IER is the ratio between IP and II. In other words, taking into account that the IPis the results of innovation and that II is the resources or raw materials to generate innovations, this rate expresses the ratio between the output by the input, a clear indication of efficiency in a system, as in the case of innovation.

Figure 1 - Diagram indicating how measures of innovation in the *Global Innovation Index* are obtained (main indices, sub-indices, pillars and sub-pillars).

Source: *Global Innovation Index* (https://www.globalinnovationindex.org)

At the third level of the hierarchy are the pillars, which serve as a basis for calculating the sub-indices. The pillars Institutions, Human Resources,andResearch, Infrastructure, Sophistication of Market and Business capture information or average characteristics of countries related to important inputs to generate innovations. They represent aspects that indicate the capacity or the potential for a country to generate innovation or the facilitation offered by the country to promote innovation. The arithmetical average of these five pillars sets the sub-index Innovation Inputs.

The Knowledge and Technology Products and Creative Products pillars reflect the products or innovation results generated by a country. The arithmetic mean of these pillars defines the Innovation Products sub index.

The last level of the hierarchy is composed of sub-pillars, three for each pillar, making a total of twenty-one, as illustrated in Figure 1. The value of each pillar is obtained with an arithmetic average of its sub-pillars. It is worth mentioning that each one of these sub-pillars is calculated considering three to five variables, which are not illustrated in the figure. Details on pillars, sub-pillars, and these indicators can be obtained on the Internet (https://www.globalinnovationindex.org/).

In 2016, for example, 82 (eighty-two) variables were used, of which 58 (fifty-eight) quantitative, 19 (nineteen) qualitative and 5 (five) were measured using questionnaires prepared by the World Economic Forum. It should be noted that some of these variables are normalized, for example, by GDP and population, before being compared with those of other countries (Dutta and Lanvin, Wunsch-VINCENT, 2016).

The 58 (fifty-eight) quantitative variables are obtained from several UN agencies, such as the United Nations Organization for Education, Science and Culture (UNESCO); the United Nations Industrial

Development Organization (UNIDO); *World Intellectual Property Organization* (WIPO), also known by its Portuguese acronym (OMPI); as well as by the World Bank; *Joint Research Center of the European Commission; Pricewaterhouse Coopers*(PwC); *Thomson Reuters; IHS Global Insight* and *Google*.

The 19 (nineteen) qualitative variables are derived from specialized agencies, such as the *WorldBank*, *International Telecommunication Union* (ITU), *UN* Public Administration Network (UNPAN) and academic institutions, such as the universities of Yale and Columbia.

Not all countries can raise the values of all variables. However, in order to cover a large number of countries and at the same time provide robustness and reliability to the Global Innovation Index and the Innovation Efficiency Rate, a country to be included in the report must simultaneously meet the following constraints (DUTTA; LANVIN; WUNSCH-VINCENT, 2016): have at least 60% of the variables that generate the Innovation Inputs; have at least 60% of the variables generated by the Innovation Products; and, provide at least two variables for each of the 21 sub pillars shown in Figure 1.

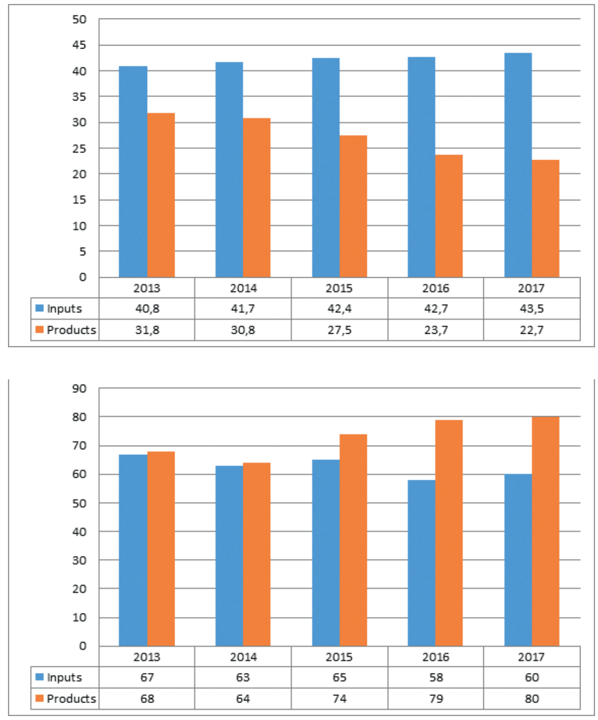
In 2016, for example, information was collected from 232 (two hundred and thirty) countries, but only 128 (one hundred and twenty-eight) simultaneously met the restrictions and were included in the report. Even so, as previously mentioned, these 128 countries together account for 92.8% of the world's population and generate 97.9% of global GDP (Dutta and Lanvin, Wunsch-VINCENT, 2016).

4.ANALYSIS OF THE NATIONAL INNOVATION SYSTEM OF BRAZIL

Figure 2 shows the evolution of the II and IP in Brazil over the last 5 (five) years, regarding absolute (top of figure) and relative values (bottom of figure), the latter aiming to assess the evolution of the insertion of Brazil in the world.

The upper part of the figure reveals diverging trends of evolution of Innovation Inputs and Innovation Outputs. While there is a consistent improvement of absolute values of II (approximately 7%, considering the extremes of the period), there is, in contrast, a consistent degradation of IP (approximately 29%). Common sense indicates precisely one behavior of similar and non-divergent tendencies, as is happening with Brazil because the Innovation Inputs are ingredients or facilitators for the generation of innovation.

Figure 2 - Evolution of Innovation Inputs and InnovationOutputs of Brazil from 2013 to 2017. Absolute valuesare shown in the upper and lower classification.



Source: The author, based on data provided by the *Global Innovation Index*.

The above expectation is corroborated by high statistical correlations[5]betweenInnovation Inputs and Innovation Outputspresented in Table 1. These correlations were calculated based on the data of 128 (one hundred and twenty-eight) countries contained in the 2016 report of the *Global Innovation Index* (DUTTA; LANVIN; WUNSCH-VINCENT, 2016).

By mathematical construction, it is reasonable that the statistical dependence or correlations between IGI and II and between IGI and PI are high, since IGI is the arithmetic mean of II and PI. Such expectation is confirmed by the Pearson Correlation values shown in the first row of Table 1 (96.0% and 97.2%). However, although there is no explicit

5 The Pearson correlation coefficient quantifies the degree of statistical dependence between two random variables, measuring, therefore, how much a variable carries information fromthe other. This is a parameter whose module varies between 0 and 1, and the larger it is, more information one variable contains from the other. A coefficient of zero indicates that the variables are independent, and a coefficient equal to one indicates that there is a perfect correlation between the variables, that is, knowing one allows a precise infer4ence of the other. Specialized literature usually assigns to ranges of values of the Pearson correlation the classification of variables weakly correlated, moderately correlated and strongly correlated. In this study, it is considered that two variables are strongly correlated when the Pearson correlation is greater than or equal to 0.75 or 75% (FONSECA, 2010).

mathematical relationship between II and PI, the correlation between these indicators is also high (88.4%), evidencing an interdependence between Innovation Inputs and Innovation Products. Therefore, it is expected that countries with good evaluations of institutions, infrastructure, human resources and the market, tend to create favorable conditions for the generation of innovation. Conversely, it is unlikely to develop an atmosphere conducive to innovation in countries with poor Innovation Inputs assessments.

Table 1 - Cross-correlations between the Global Innovation Index (GII), Innovation Inputs (II) and InnovationOutputs (PI).

Indexes	GII	II	IP
GII	1	0.969	0.972
II	0.969	1	0.884
IP	0.972	0.884	1

Source: The author, based on data provided by the *Global Innovation Index*.

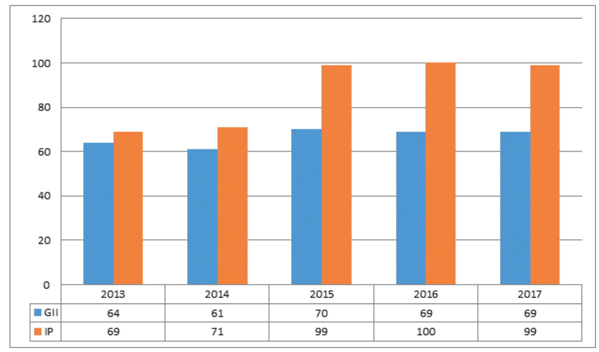
In summary, the increase in Innovation Inputs tends to increase the likelihood of improvement of Innovation Products. Although this is an average behavior, it is unlikely that a country will present a path of improvement in Innovation Inputs and degradation of Innovation Products for a long period, as has been the case with Brazil over the last five years. This anomalous phenomenon needs to be studied in depth.

The lower part of Figure2 shows similar trends to those presented in its upper part, despite episodic oscillations. It is an improvement of 7 positions in the Innovation Inputs (Brazil currently holds the 60th position in the international ranking of this sub-index) and a decline of 12 positions in Innovation Outputs(Brazil currently holds the 80th position in the international ranking of this sub-index).

Figure 3 shows the evolution of the ratings of the Global Innovation Index and the Brazilian Innovation Efficiency Ratio over the last 5 (five) years. In this figure, there is a clear degradation of the TEI due to the divergent tendencies of the II and PI behaviors, as shown in Figure 2. Brazil currently ranks 99th in the international TEI ranking, indicating that it does not can deliver innovation results compatible with the resources currently available. In the last five years, Brazil has dropped 30 positions in this criterion. This may be an indication that government actions to promote the Triple Propeller need more coordination and focus.

Similarly, there is also a deterioration of the Global Innovation Index over the past five years, but at a lower intensity. Somehow, the improvement in Innovation Inputs retains,to a little extent, Brazil'sperformance decline. In this regard, Brazil currently holds the 69th position in the international ranking, five positions worse than the one it held in 2013.

Figure 3 - Evolution of the classification of the Global Innovation Index and the Innovation Efficiency Ratio in Brazil for the period from 2013 to 2017.



Source: The author, based on data provided by the *Global Innovation Index*.

Table 2 shows the changes over the last five years, the variations in the averages of the main indicators of innovation in the world (Innovation Inputs, Innovation Outputs,and Global Innovation Index). Information was also includedon the variations of the indicators in Brazil in said period, both in absolute and relative terms.

In order to assess world dynamics, countries were grouped into four classes, according to their similarities of performance, whose limitations are quartiles, as discussed below (FONSECA, 2010). Such a grouping makes it possible to sharpen the differences between groups of countries and to facilitate analysis and identification of trends, which would be difficult if groupings by economic blocks, geographic proximity or geopolitical criteria were carried out, as was done in other studies (NATIONAL CONFEDERATION OF INDUSTRY, 2016). Class I is delimited by the minimum value of the indicator and Q1 which, in the descriptive statistics jargon, is the First Quartile, denomination attributed to the value of the study variable that separates the mass of data into two parts, the first containing 25% of the minors values of the variable and the second the rest of the data. The Class II is delimited inferiorly by the Q1 and superiorly by the Q2, the Second Quartile, better known in the area of statistics by the denomination of Median. This parameter separates the data into two sets containing the same amount of data, the first set containing the lowest value data of the variable. Since Class II is delimited lower by Q1 and higher by Q2 (Median), it is made up of 25% of the countries with the worst evaluation but that exceed the indicators of all the countries grouped in Class I (which also contains 25% of the total of evaluated countries).

Class III is delimited inferiorly by Median and superiorly by Q3, parameter known as Third Quartile and that separates the data into two sets: the first containing 75% of the data; and the second 25%, which includes the highest value data. Therefore, Class III contains 25% of all countries evaluated, which, excluding countries in Class I and Class II (totaling 50% of countries), have a worse evaluation. Finally, Class IV is delimited lower by Q3 and higher by the maximum value (highest value of the observed variable among all countries). This class contains 25% of the evaluated countries that have the highest values of the variable. Specifically, applying this rule in the case of 2016, in which 128 countries were included in the report of the GII, it can be concluded that Class IV is formed by thirty-two countries that have the highest values of the Global Innovation Index. Class III is composed of countries whose GIIare positioned between the 33rd and 64th ranks. Class II contains those countries which are classified from the 65th to the 96th position and, finally, Class I is the set formed by countries whose GIIare classified between positions 97 and 128.

Table 2 - Global percentage variation and per classes of keyGII indicators over the last five years. It also shows the variations of the averages for Brazil and the classes where this country is, represented by hatched cells.

Classes	Innovation Inputs (%)	Innovation Outputs(%)	The Global Innovation Index (%)
I	3.4	- 31.9	- 12.3
II	**3.5**	- 23.5	**- 7.8**
III	**2.4**	- 14.18	- 5.2
IV	0.7	- 3.5	- 0.9
MM	2.1	- 15.5	- 5.6
Brazil	6.6	- 28.6	- 8.8
Variation in the classification of Brazil	+ 7 positions	- 12 positions	- 5 positions

Source: The author, based on data provided by the *Global Innovation Index*.

Table 2 shows that the pace of generating innovation in the world has decreased in the last five years, particularly in Innovation Outputs. This world dynamic may also reflect the global crisis of 2008, once the same phenomenon can be observed in the indicators of productivity and GDP growth in the world, areas that are related to innovation. In particular, it is worth noting that before the crisis of 2008, the world GDP was growing at an annual average rate of around 5%, and after the above crisis, despite signs of recovery in recent years, this rhythm is much more modest, in the order of 2% (BONELLI; VELOSO; PINHEIRO, 2017).

Table 2 also shows that the world is becoming increasingly unequal in the area of innovation. The world average of Innovation Outputs dropped 15.5% over the past five years, but this decline did not occur uniformly throughout the classes, being more intense in less innovative countries. The retraction of the worst ones wasalmost 32%, while that of the best ones was only 3.5%, a retraction almost 10 (ten) times smaller in favor of more developed countries. The same trend was notedin the Global Innovation Index. In this case, the ratio between the degradation of the worst ones (Class I) and that of the best ones (Class IV) is almost 14 times.

The least developed countries have a high deficit regardingInnovation Inputs (infrastructure, human resources,and research institutions, market and business sophistication), which shows that there is room for major developments. Despite this, over the last five years,the progress of Innovation Inputs was modest, even for those countries more poorly assessed (these improved around 3.5% - Class I and Class II).

Brazil has improved Innovation Inputs well above the world average, and particularly those of the countries that integrate Class III (in which Brazil is inserted). In terms of Innovation Products, Brazil only achieved better results, on average (Class II and Class IV countries), and are lagging behind their direct competitors (Class II), and especially for the most innovative countries (Class III and Class IV). This same behavior occurred with IGI. If these trends are maintained, Brazil may fall from Class II to Class I, becoming among the 25% worst innovative countries in the world, among those evaluated by the GII.

To analyze in greater depth, the global trends of the three main parameters of the GII, Figures 4, 5 and 6 show, respectively, the evolutions of diagrams of boxes of Innovation Inputs, Innovation Outputsand Global Innovation Index over the last five years. At the bottom of these figures, the values of the main statistical parameters of these charts are shown.

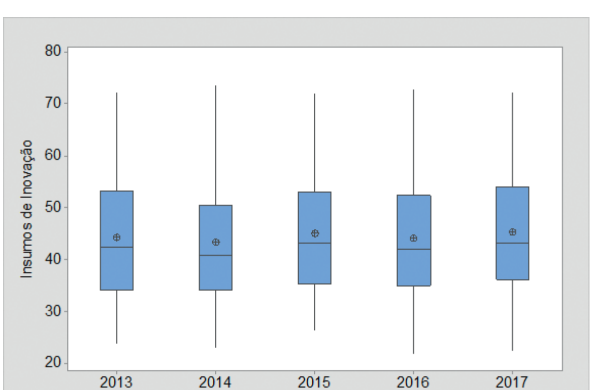
The ends of the straight lines of the Box Diagrams represent the minimum and maximum values of the indicators for each year. The horizontal straight lines that delimit the boxes, specifically, the bottom part, located within the larger (larger box) and the superior rectangle, denote, respectively, the Q1, Q2 (Median) and the Q3. Finally, the plus sign circumscribed by a circumference located inside the box represents the average of the data collected.

The figures show that the means are larger than the medians. This indicates that the data are not distributed symmetrically and that the scattering of the 50% of the countries with the worst evaluations is less than the 50% better evaluated. One consequence of this is that shifts in ranks in the world rankings among the best-evaluated countries are more difficult to make than shifts in ranks among the worst-rated, whose indicator differences are relatively minor.

With respect, particularly, to Figure 4, it can be seen that there was a reduction of the minimum value and an increase in Q1, extending the amplitude of Class I in 33% in the period (from 10.3 in 2013 to 13.7 in 2017), setting to a greater dispersion of the indicators of countries in this class.

As the median (Q2) progressed less than Q1 and more than Q3, there was a reduction of the amplitude of Class III and, mainly, of Class II, leading to greater densification of the countries of these classes, where Brazil (2013) until 2015 Brazil belonged to Class II and, from 2016, Brazil became Class III). The amplitude of the Class II varied from 8.3 in 2013 to 7.1 in 2017, a retraction of 14.5%. The amplitude of Class III ranged from 10.85 in 2013 to 10.7 in 2017, a reduction of approximately 1.4%.

Figure 4 - Evolution of the Box Diagram of Innovation Inputs from 2013 to 2017 and their statistical parameters.



PARAMETER	YEAR					
	2013	2014	2015	2016	2017	%
Min	23,7	23	26,3	21,7	22,4	-5,5
C1	34	34	35,35	35	36,1	6,2
C2	42,3	40,8	43,1	42,05	43,2	2,1
C3	53,15	50,45	53	53,325	53,9	1,4
Max	72,3	73,6	72,1	72,9	72,3	0
AT	48,6	50,6	45,8	51,2	49,9	2,7
Media	44,3	43,4	45	44,2	45,2	2,1

Source: The author, based on data provided by the *Global Innovation Index*.

Under these conditions, small relative variations among countries which belong to these classes can result in substantial changes in classification, a fact that actually happened with Brazil,whichadvanced 7 (seven) positions in the international ranking of Innovation Inputs, on account of an increase of only 6.6% in its indicator in the face of a 3.5% increase in the average of Class II. In other words, a small advantage for Brazil, when compared with the average behavior of the class, allowed a substantive classification improvement in the international ranking.

Finally, the amplitude of Class IV increased from 19.15 to 18.4 in 2017, a reduction of 4%. Despite this reduction, this is still the class with the greatest range, that is, there is a greater separation or dispersion among the indicators of the countries. Therefore, it is in it that there is a greater tendency of stability in the classifications of the countries.

Figure 5 shows the effect of the reduction of Innovation Outputsover the past five years, marked byan evidentdownward displacement of the boxes with the passing of the years. However, other aspects come to the fore when statistical parameters represented therein are analyzed.

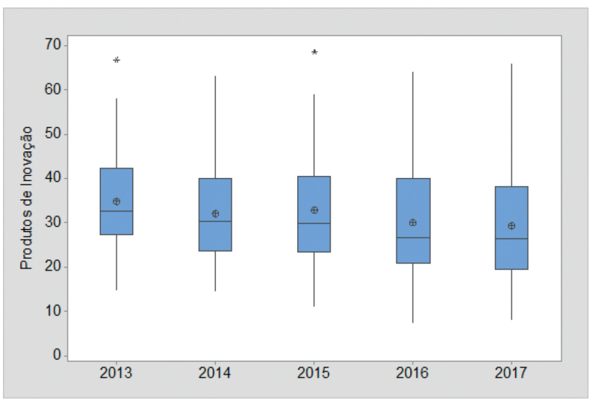
There was a substantial reduction in the minimum value (45%) over the last five years, but the maximum value of Innovation Outputs virtually did not change, reflecting a significant increase of the TA (Total Amplitude)[6] in the period. This is clear objective evidence of increased inequalities among countries in the field of innovation. This inequality is further reinforced by the fact that the percentage decreasesof Q1, median (Q2) and Q3 are successively smaller. There was thus a magnification of the amplitudes of all classes, except for Class I, whose Amplitude dropped to 9.4% (from 12.7 in 2013 to 11.5 in 2017). Class II, in which Brazil is inserted, had thehighest

6 Total Amplitude is defined as a data set as the difference between the higher value given by the smaller of this set (TA = maximum - minimum) (FONSECA, 2010).

increase in Class Amplitude[7], from 5.3 in 2013 to 6.8 in 2017, a 28.3% increase. The amplitude of Class III went from 9.65 in 2013 to 11.8 in 2017, an increase of 22.3%. The amplitude of Class IV went from 24.45 in 2013 to 27.7 in 2017, an increase of 13.3%.

It is worth mentioning that despite the aforementioned variations, Class II is still the one with the lowest Class Interval. Therefore, it is in it that small changes in country indicators may reflect significant changes in rankings in the international ranking due to the greater relative density. This actually occurred with Brazil, which in spite of not performing much worse than the average behavior of the Class II countries (national degradation of 28.6% versus Class II degradation equal to 23.5%), 12 positions in the international ranking.

Figure 5 - Evolution of the Innovation Boxes Diagram for 2013 through 2017 and its main statistical parameters.

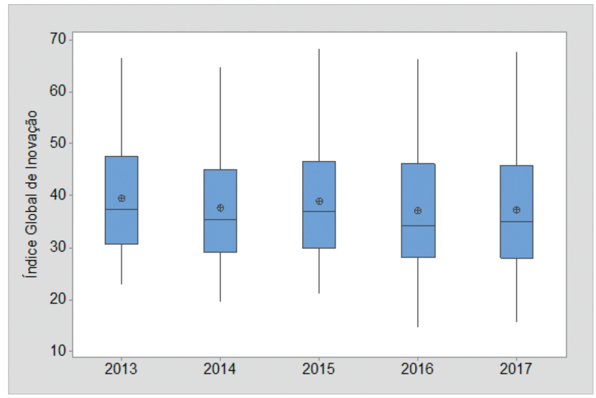


PARAME-TER	YEAR					
	2013	2014	2015	2016	2017	%
Min	14,6	14,6	11,1	7,4	8,0	-45,2
C1	27,3	23,25	23,3	20,875	19,5	-28,6
C2	32,6	30,25	29,7	26,6	26,3	-19,3
C3	42,25	39,95	40,35	39,925	38,1	-9,8
Max	66,7	63,1	68,6	64,2	65,8	-1,3
AT	52,1	48,5	57,5	56,8	57,8	10,9
Media	34,7	31,9	32,7	30	29,3	-15,6

Source: The author, based on data provided by the *Global Innovation Index*.

Figure 6 presents the evolution of the Boxes Diagram of the Global Innovation Index over the last five years. As the average is greater than the median, the developed countries have more spread out indicators. Furthermore, it appears that these statistical parameters declined; however, the degradation of the median was a little more significant in percentages.

Figure 6 - Evolution of the Boxes Diagram of the Global Innovation Index from 2013 to 2017 and their main statistical parameters.



PARAME-TER	YEAR					
	2013	2014	2015	2016	2017	%
Min	22,9	19,5	21	14,6	15,6	-32,9
C1	30,75	29	29,95	28,12	28	-8,9
C2	37,4	35,35	36,8	34,05	35	-6,4
C3	47,55	45	46,5	46,07	45,8	-3,7
Max	66,6	64,8	68,3	66,3	65,8	-1,2
AT	43,7	45,3	47,3	51,7	50,2	14,9
Media	39,5	37,7	38,9	37,1	37,3	-5,6

Source: The author, based on data provided by the *Global Innovation Index*.

Graphically, a large reduction of the minimum IGI value is observed, and the table shows that this reduction was almost 33% over the last five years. In sum, the reductions in the minimum value, Q1 and Median indicate a major deterioration in the performance of the poorly evaluated countries (50%, about 64 worst IGI countries).

On the other hand, it is verified that the maximum value of the sample practically did not change during the last five years, there was only a small reduction of the maximum value (1.2%). These data indicate that the world is becoming increasingly unequal in terms of the Global Innovation Index and that Brazil is among those who are lagging behind.

The Class I Amplitude ranged from 7.55 in 2013 to 12.4 in 2017, an increase of approximately 64%, due to a large reduction in the minimum data value. In this way, it is possible to increase the dissemination or dispersion of the indicators of the Class I countries, as well as to deepen the distance between these countries and the most developed ones.

The amplitude of Class II ranged from 6.65 to 7 in 2013, a small increase of approximately 5%. The amplitude of Class III ranged from 10.15 in 2013 to

7 Class Amplitude as the difference between the upper and lower limits of the class. In this case, the amplitude of Class I is given by Q1-Min; the amplitude of Class II is given by Q2-Q1, etc. (FONSECA, 2010).

10.8, a modest increase of approximately 6%. Finally, the amplitude of Class IV ranged from 24.45 in 2013 to 27.7 in 2017, an increase of approximately 13%.

Increasing the amplitudes of all classes is another strong and uncontested indication that the world is getting much more unequal in terms of the Global Innovation Index.

Finally, it is worth noting that Brazil belongs to Class II, whose Amplitude is the lowest among all classes. Therefore, there is a large density of indicators and, as a consequence, small variations in the absolute values can result in significant changes in the classifications of countries. This fact occurred inBrazilbecause its degradation in the last five years (8.8%) was only slightly worse than the degradation of the average of the class (7.8%).Nonetheless,Brazilstill lost five positions in the international ranking.

5. FINAL CONSIDERATIONS

In this article, we analyzed the evolution of the main indicators of the Global Innovation Index from 2013 to 2017, particularly the Global Innovation Index and the Innovation Efficiency Ratio, to draw conclusions about global trends and the Brazilian National Innovation System. Unlike other studies which group countries based on geopolitical, geographic criteria or economic blocs, in this study the countries were grouped into classes with similar performance characteristics, which allowed us to highlight disparities among groups of countries and emphasize out trends.

It was found that retraction and increasing inequalities characterized the global dynamics of the last five years. Severe retraction in Innovation Outputsand the Global Innovation Indexwere observed, but they were much more intense in the backward countries.

In the national context, it was found that variations in classifications of indicators are influenced not only by national and worlddynamics but mainly by the behavior of the class to which Brazil belongs because that is where their main competitors are. In this sense, the degree of dispersion or spreading of class underdiscussion is fundamental to explain any variations in Brazil's classification.

It was observed that the Innovation Inputs, formed by the pillars Institutions, Human Resources and Research, Infrastructure, Market Sophistication and Business Sophistication, have been improving consistently, but modestly, in the last five years. On the other hand, it was found that the InnovationOutputs, formed by the pillars Knowledge and TechnologyOutputs and Creative Outputs, have been worsening, also consistently, in the same period. This is counterintuitive because the inputs facilitate and help to trigger innovation processes that are embodied in their products.

The bad classification of Brazil in relation to the Innovation Efficiency Ratio and the sharp drop in performance in this indicator over the last five years (30 positions), caused by the disparate behaviors of variations in indicators of Innovation Inputs and Innovation Outputs, reflects the national inefficiency in converting their inputs into innovation. As a reflection of that, currently, Brazilholds the 99th position in the international ranking of the IER, according to the GII.

Improvements in education at all levels, an increase of investments in R&D and the strengthening of links between academia, industry,and government are some of the main measures continually pointed out to enhance the performance characteristics of the Brazilian National Innovation System. Thus, the recent actions of the Department of Science, Technology,and Innovation of the Brazilian Army gain importance in order to transform their Science and Technology Institutions and the creations of SisDIA and AGITEC, having as a theoretical framework the Triple-Helix paradigm and as basic guidelines the process of Transformation of the Army. If successful, such initiatives may bring benefits to the strategies of Defense and Development, as well as promote greater synergy between military and civilian sectors of Brazilian society, in accordance with the recommended procedure in national documents of the political and strategic levels toward the area of Defense.

In the continuation of this work, we intend to analyze in greater depth the evolution of the pillars and sub-pillars that make up the Innovation Inputs and the Innovation Products.

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