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National Innovation Policy: a matter of economic growth, development, and national sovereignty

Política Nacional de Innovación: una cuestión de crecimiento económico, desarrollo y soberanía nacional

Abstract: Despite the remarkable economic expression, the impressive internal market, and the diverse innovation incentive policies, such as the 2004 Innovation Law, Brazil's National Innovation System (NIS) still has modest performance indicators. According to the 2019 Global Innovation Index report, the country is ranked 66th in the World Innovation Ranking. Based on documentary and bibliographic research, we seek to explain the reasons for the inefficiency of Brazil's NIS. To inspire appropriate policies, successful examples are reported from countries that have progressed through innovation and recent efforts promoted by the Brazilian Army in this direction. Based on these studies, we present propositions to be considered in the definition of a holistic and long-term National Innovation Policy, capable of coordinating government actions directed towards this sector and promoting economic growth, development and assuring National Sovereignty.

Keywords: National Innovation System. Innovation. Global Innovation Index. Triple Helix.

Resumen: A pesar de la destacada expresión económica, del pujante mercado interno y de las diversas políticas de incentivo a la innovación, como la Ley de Innovación de 2004, Brasil presenta indicadores de desempeño bastante modestos. Según el informe de 2019 del *Global Innovation Index*, el País se encuentra en la 66ª posición en la clasificación mundial de innovación. Basado en la investigación documental y en la bibliográfica, se busca explicar las razones de la ineficiencia del Sistema Nacional de Innovación (SNI) brasileño. Para inspirar políticas adecuadas, son presentados ejemplos exitosos de países que avanzaron por medio de la innovación. También, son enumerados emprendimientos recientes que son promovidos por el Ejército Brasileño en el campo de la gestión de la innovación. Con base en esos estudios, son discutidas propuestas que serán consideradas en la definición de una Política Nacional de Innovación holística y de largo plazo, capaz de coordinar las acciones gubernamentales que son direccionadas al sector y de promover beneficios al crecimiento económico, al desarrollo y a la Soberanía Nacional.

Palabras clave: Sistema Nacional de Innovación. Innovación. Índice Global de Innovación. Tríplice Hélice.

Décio Luís Schons
Exército Brasileiro, Departamento de Ciência e Tecnologia (DCT).
Brasília, DF, Brasil.
schons79@gmail.com

Hildo Vieira Prado Filho
Exército Brasileiro, Departamento de Ciência e Tecnologia (DCT).
Brasília, DF, Brasil.
hildoprado1960@gmail.com

Juraci Ferreira Galdino
Exército Brasileiro, Agência de Gestão e Inovação Tecnológica (AGITEC).
Rio de Janeiro, RJ, Brasil.
jfgaldino675@gmail.com

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1 Introduction

Throughout history, countless technological advances, originally intended for military products and systems, have generated spillovers to civilian sectors, creating disruptive innovations with major benefits for society (MAZZUCATO, 2014). Particularly in the 20th century, complex military research has driven innovations and economic growth for pioneering countries.

However, in the last thirty years, globalization has intensified, supported by impressive advances in digital communications with planet coverage; and, more recently, in the wake of the Fourth Industrial Revolution, by the pace of innovation that reached unusual levels in human history (SCHWAB, 2016). In summary, with governments supporting basic and applied research, developments focused on the civilian market have become the major drivers of scientific and technological advances.

Several factors contributed to this context, such as the Open Innovation model (CHESBROUGH, 2012); the creation of innovation networks that cross national borders; and the proliferation of innovation environments, such as science parks, centers, and districts. Currently, there are numerous demonstrations of "Spin-in" in which innovations intended for the conventional market are enhanced and integrated in order to generate new capabilities in the area of Defense (LESKE, 2018). As a result, greater synergy between military and civilian research and development (R&D) sectors, as well as the adoption of the Open Innovation and Triple Helix (ETZKOWITZ, 2005, 2010) models in Defense, constitute a global trend guiding the planning of national directives.

Development and Defense strategies are increasingly dependent on innovations (GALDINO, 2019b). Indeed, in a globalized world, guided by great competitiveness, where new and challenging asymmetric threats emerge, innovation becomes fundamental for increasing productivity, economic growth, and autonomy in sensitive areas of the National Defense.

The Defense area is highly demanding of science, technology, and innovation (LONGO, 1984). Because of this, the Defense White Book (BRASIL, 2016a), National Defense Policy and National Defense Strategy (BRASIL, 2016b) emphasize the association, linkage, and mutual dependence between the Defense Strategy and the Development Strategy, as well as the need for scientific and technological development to promote autonomy in important areas such as cybernetics, nuclear, and space areas. The synergy between civilian and military institutions that engage in promoting innovation can make the use of public resources more efficient, effective, and streamlined, especially in a country under-developed in several sectors of society and with reduced resources to invest in science and technology, especially in the area of Defense.

The Brazilian Army's Science, Technology, and Innovation System (SCTIEx) is currently in a transformation process, aiming to create a good innovation environment; strengthen the Brazilian Industrial Defense Base; and, in particular, increase integration and cooperation between academia, government, and industry.

Considering the interaction of the Sectoral Innovation System of the Defense Sector and, in particular, of the SCTIEx with the National Innovation System (NIS) (AZEVEDO, 2018, p. 151), it is natural that the innovation capability of the former depends primarily on the latter. Therefore, having a strong and thriving NIS, compatible with Brazil's size, economy, market, and wealth, is essential for the National Defense.

Despite the various policies and actions toward innovation over the last fifteen years, Brazil's innovation capability is quite modest, as suggested by several indicators. For example, Brazil ranks 66th in the international innovation ranking, according to report of the 2019 Global Innovation Index[1].

Therefore, it becomes imperative to establish a broad National Innovation Policy (NIP) to take the country out of this uncomfortable and risky situation, especially nowadays, when knowledge is the most important resource. While raw materials accounted for 30% of the world's gross product in the 1960s, today they represent less than 4% (OPPEINHEMER, 2011, p. 9). Empirical evidence obtained from recent history of many countries, such as Finland, shows that technological innovations transform production and cause disruptions that maintain the dynamism of the economy, contributing more to the country's Gross Domestic Product (GDP) than natural resources exploration (MONTEIRO, 2019a).

Innovations are not completely the result of scientific research. A classic example is the "container", according to Longo (1989), a technology that greatly impacted the transportation sector over recent decades. However, several studies (AMARANTE, 2009; CHESBROUGH, 2012; FIGUEIREDO, 2015; LONGO, 1984; ROSENBERG, 1991; SCHWAB, 2016) show that the innovations capable of boosting the economy, development, and autonomy in strategic sectors of a country's defense area increasingly depend on high investments in Science and Technology, especially on basic and applied research, as well as R&D projects.

From this perspective, innovations depend on long-term policies and actions. They result from a time-consuming process that begins with the development of ideas and concepts, progress on successive levels of technological maturation, and finalizes with the production and marketing of products and services (AFUAH; BAHRAM, 1995; TROTT, 2008).

The Armed Forces' strategic projects also progress on a long development cycle, comprising the training of specialized personnel, and advancing from state-of-the-art research, to the full mastery of R&D and production capabilities for Defense Systems and Products, particularly the critical technologies embedded in them. These are the developments of high technological value, such as the Software-Defined Radar and Radio Program, under the responsibility of the Army Technology Center, and the Army Strategic Projects, managed by the Army Projects Office, whose portfolio consists of several complex systems, such as the Sisfron (Integrated Border Surveillance System), Guarani (family of wheeled armored vehicles), and Astros 2020 projects.

1 Available from: https://www.globalinnovationindex.org/gii-2019-report. Access on: Oct. 23, 2019.

In developing countries, that don't own the production of sensitive technologies, the innovation process is slow. This process becomes instable when the NIS is inefficient, as it happens in Brazil. In this context, long-term policies are essential. Several countries, such as Israel, South Korea, and Finland, implemented long-term policies and have become true champions of innovation, economic growth, and social development.

In addition, in some high-tech areas, the existence of a State policy is essential to compensate for market failures, since the investment's returns to corporations are uncertain, slow, and often small when compared to the benefits to society. This is particularly important in the case of the Defense Industry, which produces for a monopsonistic market and whose capacity must be maintained and improved for the benefit of National Sovereignty.

Given the late industrialization process, an inefficient innovation environment, and the precarious mastery of basic technologies, how to develop a long-term NIP capable of putting Brazil among the innovative countries?

Based on documentary and bibliographic research, this article aims to shed light on this problem. It seeks to explain the reasons for the inefficiency of the NIS and poor results of public policies toward the sector in recent years. In an attempt to inspire appropriate policies, it refers to successful examples of countries that advanced, by innovation, throughout the 20th century, and recent ventures of the Brazilian Army to boost their innovation system. Based on the diagnosis and successful experiences, it is discussed topics to be considered in the development of a comprehensive and long-term NIP.

2 Diagnosis of Brazil's National Innovation System

Innovation is a complex and multidisciplinary phenomenon that goes beyond the scientific and technological field and interacts with various sectors of society. It results directly or indirectly from several actors and factors that constitute the so-called NIS (CIMOLI, 2014; GODIN, 2009; LUNDVALL, 2010; NICOLAU; PARANHOS, 2006).

The term "National Innovation System" was coined by Freeman (1995) to designate elements whose activities and interactions contribute to the creation, advancement, and dissemination of a country's technological innovations. The intention in adopting the term "System" is to show that the efficiency of the innovative process depends not only on the performance of isolated elements but on the interactions between them. Accordingly, the term "National" was included not only to define the unit of analysis (country), but also to reflect the holistic nature of the subject. Therefore, innovation does not depend only on companies, universities or research organizations but also on how they interact with one another and with several other actors, and how institutions, including political ones, affect the development of the system (CASSIOLATO; LASTRES, 2005). Interconnections are crucial to the concept of the system and may have the form of joint research, personnel exchange, intangible assets protected in co-ownership, purchase of equipment for collective use, sharing of laboratory infrastructure, technological transfer, etc. (MONTEIRO, 2018).

The real perception of the holistic nature of innovation and the need for interconnections between the various actors involved in its process is essential for an in-depth understanding of a NIS and its dimensions, as well as to conduct analyses, studies, and diagnoses. These, in turn, will support strategic planning aimed at triggering policies and actions to make the national innovation process more efficient and create conditions to increase productivity, competitiveness of the economy sectors, economic growth, and national development, aiming at autonomy in areas that are strategic for national defense.

Measuring the capability of a country's innovation system is a very complex task, but necessary to support the definition of public policies and evaluate the results of strategic actions arising from these initiatives (KHEDHAOURIA; THURIK, 2017). Several studies and researches are conducted with the objective of developing innovation indicators (TOPÇU, 2016). Significant advances have occurred in this area, such as the Innovation Efficiency Rate produced by the Global Innovation Index (GII), which combines more than eighty variables that attempts to reflect a NIS[2].

Several studies analyze the NIS of Brazil in order to identify its main bottlenecks and trends (DE NEGRI, 2018; DE NEGRI; SQUEFF, 2016; GALDINO, 2018, 2019a; MENEZES FILHO et al., 2014). Despite the diversified methodological approaches, indicators, and time-series windows adopted in these analyses, the conclusions regarding the essential aspects are similar. The discussion on bottlenecks sheds light on the major national challenges to be overcome to make the innovation environment efficient and effective.

Considering the GII, Brazil has not obtained satisfactory innovation indices. For example, since 2013, when this organization consolidated the architecture of indicators, composed of subindices, pillars, and subpillars, Brazil does not rank among the sixty most innovative countries in the world. The situation is even worse regarding the Innovation Efficiency Rate. In this case, Brazil is not even included among the ninety most efficient countries in the world.

Moreover, trend studies based on these indicators do not suggest a better future if current trajectories are maintained (GALDINO, 2018, 2019a). On the contrary, they foresee an increasing distancing from developed countries. According to these studies, the main bottlenecks to innovation are Business Environment, Political Environment, Education (elementary, secondary, and higher education), General Infrastructure, Credit, and Innovation linkages (Triple Helix). They also indicate that the Brazilian NIS is bureaucratic, unstable, inefficient, and insecure, making private investments difficult, especially medium and long-term ones. Therefore, strategic planning prioritizing policies and actions that contribute to reduce the bottlenecks mentioned above and creating favorable conditions for the development of innovation in Brazil is urgent, subject to progressive loss of competitiveness and distancing from the Global Value Chain and incessant increase in the risk of Brazil appearing in the globalized world as mere market and supplier of *commodities*, mineral resources and small value-added products.

2 Further information on GII indicators may be obtained from https://www.globalinnovationindex.org.

The very low quality of secondary and elementary education is one of the main national bottlenecks. In the OECD Programme for International Student Assessment (PISA), Brazil ranked among the last ones in mathematics tests (SASSAKI et al., 2018). Higher education also had a very poor evaluation, resulting from the small number of professionals linked to the areas of exact sciences and engineering. Brazil's strength was the exceptional performance of R&D activities, despite the small number of researchers per million inhabitants, when compared with the world averages and, particularly, with those of the most innovative countries (GALDINO, 2019a).

In an apparent paradox, Brazilian scientific production has grown in recent years. The percentage production of scientific articles by Brazilian authors in the world production increased from approximately 1.2% in 1991 to more than 3% in 2015 (DE NEGRI, 2018). Despite this very significant increase, the quality of the national academic production, expressed in terms of citations, has not been growing in the same proportion. On the contrary, Brazil is falling behind in this respect. It is relevant to highlight that the national scientific production is very low in the areas that foster innovation in the Knowledge Era and Fourth Industrial Revolution, such as engineering, computer science, and materials science. This scientific production profile is very different from that of innovative countries, in which publication in these areas represents a very significant portion of the total production. In Brazil, the areas that have a higher performance percentage are Dentistry, Veterinary Medicine, Arts, and Humanities (DE NEGRI, 2018; MENEZES FILHO et al., 2014). From this perspective, the Brazilian conjuncture shows no reflections of a comprehensive and long-term national policy capable of creating a human resources training structure focused on innovation. What exists is a disconnection between the areas in which Brazil has greater competence and those that generate innovation and economic growth with greater efficiency and effectiveness. By analyzing the areas more connected with innovation, it is observed that scientific production in Brazil is below the world average and much lower than in highly innovative countries.

In terms of patents, Brazil has a very modest performance. Besides, 80% of the patents filed in the national territory come from non-residents and only 7% come from national companies. This situation is quite different from what occurs in highly innovative countries, in which residents account for a large percentage of filings, most of which are from companies (DE NEGRI, 2018; MENEZES FILHO et al., 2014), a sector responsible for promoting innovation with the launch of new products and services in the market.

Even in areas in which Brazil has good academic competence, excessive bureaucracy, and a lethargic and protectionist business environment make it difficult to exploit the knowledge produced in universities for the design of new products. The 2004 Innovation Law led to the creation of Technological Innovation Centers and increased incentives for the protection of intangible assets originating in Scientific, Technological and Innovation Institutions (STI). Also, invention patents started to be considered as a way to evaluate national researchers by funding agencies. As a result, the number of patent applications from Brazilian universities increased. However, there are no indications of an

increase in the number of technology licensing or negotiations of these patents. Therefore, increasing the number of patents is not enough: the desired outcome is that such patents be transferred to the productive sector and generate innovations.

The number of researchers per million inhabitants in Brazil is very low, even lower than in Argentina and Chile, and most of them are outside of the industrial sector, but in academia and public agencies. The number of engineers per million inhabitants is also quite small. Despite that, there is still unemployment in the engineering sector, and average wages are kept stable over time, indicating that there is no market to absorb a higher percentage of graduates from engineering fields. Indeed, the national market is not competitive and requires little in terms of innovation.

Collaborations between the government, academia, and companies have been promoted by several policies, such as the Innovation Law, and funding models, such as EMBRAPII and Inova applications, but the results are not satisfactory. In fact, GII indicators show a decrease in indices that evaluate these collaborations in the last five years (GALDINO, 2019a). Developing a culture of innovation to reduce fragmentation and discoordination between NIS actors is essential, particularly of members of the Triple Helix (AZEVEDO, 2018; CUNHA; AMARANTE, 2011).

Tax incentives for innovation (Law of Good and Computer Law) have increased over the recent years in relation to gross domestic product (GDP), credits for innovation from BNDES and FINEP grew considerably from 2007 to 2014, and so did the domestic expenditure in R&D relative to GDP, however, innovation indicators do not detect a trend of improvement.

In Brazil, universities – whose main vocations are knowledge generation, training, specialization, and improvement of human resources – are home to the largest share of scientific research infrastructure. Differently from which occurs in developed countries, in Brazil there are few structures or institutions dedicated exclusively to applied scientific research, such as EMBRAPA, FIOCRUZ, the Brazilian Center for Energy and Materials Research, and military STIs, such as the Army Technology Center.

In a broad survey conducted by IPEA (Institute of Applied Economic Research) on the domestic research infrastructure, covering about 2,000 national laboratories, it was found that Brazil has few large laboratories, indicating that investments are spread largely for small laboratory infrastructures (DE NEGRI; SQUEFF, 2016).

Unlike highly innovating countries, in Brazil, ministries, such as Defense, Health, and Agriculture, have reduced resources to invest in innovation. Truly, MEC and MCTIC account for the vast majority of investments in research. This has an important consequence: in countries where these ministries have a significant volume of resources to invest in innovation, there is a greater propensity for the development of Science and Technology as a mission, therefore, to solve real medium and long-term problems, driving the generation of innovations within the corresponding sectors. On the contrary, in Brazil S&T prioritizes the generation of knowledge rather than its appropriation for economic growth and social development.

Regarding Infrastructure, the mean of global indicators has been growing at a faster rate than the national indicators. With the exception of the ICT area, Brazil has been losing positions in the international ranking, according to GII indicators of the last five years.

Among the national indicators obtained by the GII, those associated with institutions, the political environment, regulatory environment, and business environment are ranking poorly. According to these indicators, Brazil is among the countries with the worst performance[3]. Reforms are urgent in order to automatize and simplify tax charges and procedures for opening and closing companies, as well as reducing bureaucracy and providing legal certainty to medium and long-term private investments.

This summarized diagnosis highlights some of the main challenges in the search for improvement of the Brazilian innovation capability. It is interesting to mention the adoption of some initiatives carried out over the last 15 years aimed at solving some of the problems previously pointed out, but without significant results (MORAIS, 2017). A striking example is the Law of Good (Law No. 11,196/2005), which implements mechanisms to attract more PhDs and masters to the industrial sector, by remunerating these researchers with government funds. However, this approach does not seem to be effective, especially regarding PhDs, since most of them remain employed in the public sector, as already mentioned. This issue needs to be dealt with holistically: if the market does not demand innovation, specific incentives are ineffective.

3 Successful International Experiences in Innovation

South Korea has managed to overcome its economic difficulties and become prominent in technological innovation. Since the 1980s, this country has adopted some public policies aimed at scientific and technological development and at obtaining a high-tech industrial base by training and attracting high-level scientists and engineers, strengthening education, conducting training programs abroad, and repatriating talented individuals. It increased industrial productivity by promoting partnerships between STIs, universities, and companies and cooperation with other countries. It recognized the importance of science and technology for the development of the country and created research institutes in specialized fields. It prioritized the development of technological capability by training scientists and engineers. It attracted young people for science, incentivized the development of industrial property, and opened the market (FREITAS et al.,1989; PONTES, 2019).

Another example of success is Japan, which has become a world power due to its scientific and technological development. To achieve development goals in the 1980s, there were major investments in R&D both by the government and the business sector (SICSÚ, 1989, p. 37). Knowledge about global legislation on industrial property was emphasized and the education sector was given top priority, giving Japan one of the best educational systems in the world. Thus, they built an exceptional capacity to innovate

3 In the 2019 report, Brazil appears in the 80th position in a set of 120 countries. https://www.globalinnovationindex.org/analysis-indicator

through imitation by acquiring imported products that were improved and launched in the domestic and international markets.

In Israel, which has also become prominent in the technology sector, education is the government's priority. In addition, also in the late 1980s, the country already had a considerable level of interaction between industries and universities (CALÁBRIA; SICSÚ, 1989).

This brief report shows that countries with disparate sociocultural realities prioritized the provision of exceptional quality education at all levels, focused on the training of personnel in areas dedicated to innovation, established good coordination between research centers, the government, and the productive sector, introduced policies to foster R&D activities, valued the production and dissemination of knowledge, as well as its practical application and consequent appropriation, through intellectual property.

The fascinating book "Enough of Stories! The Latin American Obsession with the Past and the 12 Keys of the Future", by journalist laureate Andrés Oppenheimer, shows how the education improvement at all levels, especially in elementary and secondary degrees, the valuation of professional educators, and the incentive of science, technology, and innovation have transformed, over the past century, the trajectories of countries such as Finland, Singapore, South Korea, India, China, and Israel. The trajectory of these countries is compelling empirical evidence that improving education, science, technology, and innovation is not an impossible task. It also shows that the countries that advance are not those that sell raw materials or basic manufactured products, but those that produce goods and services of higher added value, for a very simple reason: we are currently experiencing the knowledge era in the economy.

It is intriguing to realize that the policies above worked very well in countries with such unequal political, economic, and social structures. Other studies show that practices such as emulation, the adoption of industrial policy, investment in technological innovations, and active participation of the government led countries with large sociocultural differences to development (ZAGATO, 2019).

An invitation to reflection, the book highlights the need for a strategy that values earlier educationfocused on sciences, without leaving aside humanistic values. It shows the importance of valuing, recognizing, respecting, and rewarding the professional educator at all levels with the best wages in order to attract young people to this profession. This is certainly a very inspiring practice!

Suzigan and Albuquerque (2008) found that the accumulation of monetary and financial resources was another factor that contributed to the scientific and technological progress of several nations, as it enabled the creation of credit for funding research and development, as well as fostering the industrialization process. Based on the outcomes of the New Deal[4] American program, they conclude that a solid financial system – along with the consolidation of public finances with fiscal and tax austerity – was a precondition for an efficient innovation system to be created in the U.S., with significant federal public spending on research and development, which enabled the country to excel since the 1950s.

4 The *New Deal* was the name given to the series of programs implemented in the United States between 1933 and 1937 with the aim of recovering and reforming the American economy.

Analyzing the American NIS, Rosenberg (2000) compares the universities in the USA with those of other countries. Based on his findings, he concluded that scientific and technological institutions will better contribute to technological development if they respond to economic demands; decentralize activities; need to compete for resources with other STIs to carry out their projects; compose a wide network of information that enables a high degree of specialization and diversity; and remain committed to applied research since the academic training of human resources.

These factors bring scientific and technological institutions closer to companies and keep them aware of the real demands of the market. The closer this relation, the greater the positive impact on economic growth and the efficiency of the NIS.

4 The Brazilian Army's Contributions to Foster Innovation

As a result of a broad study conducted by the Chief of Staff of the Brazilian Army (EB) a transformation process began with the primary objective of transmuting the structures conceived under the Industrial Age into an organization capable of facing the challenges posed by the Knowledge Age (BRASIL, 2010; PRADO FILHO, 2014).

This transformation process is supported by actions grouped into seven vectors (BRASIL, 2010), being the "S&T and Modernization of the Material" the most interesting in the area of technological innovation. In this direction or vector, it is highlighted the technologies that compose the Knowledge Age and the Fourth Industrial Revolution, technological intelligence and forecasting, as well as organizational changes, including with the creation of new structures and processes, such as the Technology Management and Innovation Agency of the Brazilian Army (AGITEC).

At the core of the transformational process of the Army Science, Technology, and Innovation System (SCTIEx), AGITEC deals with crucial areas of the Knowledge Age and with modern innovation models, whose implementation, in its fullness, will represent a breakthrough in the actual model still in use by the SCTIEx, particularly regarding R&D activities.

Knowledge Management, Intellectual Property Management, Technological Information and forecasting, and Innovation Culture are complex, multidisciplinary, and comprehensive areas that start to gain prominence in the Brazilian Army with the creation of AGITEC. Accordingly, the Open Innovation and Triple Helix models (CHESBROUGH, 2012; ETZKOWITZ, 2005), which have long been proposed and discussed worldwide, are difficult to implement, especially in the area of Defense and National Security, particularly when political, economic, and social structures have developed over centuries a culture of little interdependence and cooperation between the main actors of a NIS and, especially, when the concept of National Sovereignty is not among the basic and pressing needs of society.

Moving from a traditional innovation model, commonly called Closed Innovation, in which civilian participation in Defense R&D activities occurs mainly in the form of contracts, to a cooperative model of innovation in which diverse actors (Armed Forces, Universities, incumbent companies and startups, Angel Investors, and

Development Agencies) participate in the same enterprise and share results, imposes important and intricate challenges, such as the management of secrecy, intellectual property, technology licensing and innovation returns, aside from the common challenges of creating innovation in an area of high added value and high technological risk, such as Defense. Despite these challenges, the rupture of the actual model becomes imperative, because the increase of the participation of Brazilian society in Defense, especially in those focused on the areas of Science, Technology, and Innovation, is a necessary condition to meet the demands of a continent country, sovereignly. With the creation of SisDIA (Defense, Industry, and Academy Innovation System) and AGITEC, the Army put a high priority on strengthening the links between academia, industry, and government.

Committed to its constitutional mission, the Army undertakes an endless journey to improve management and governance processes using established concepts, modern procedures, and good practices in several areas under its operation. Along its transformational process, the Army identified the technological forecasting as an essential area that needs improvement to support high-level decision-makers regarding the knowledge and technologies that must be obtained in the medium and long term for the benefit of the Permanent National Goals (ESCOLA SUPERIOR DE GUERRA, 2019).

Therefore, the Brazilian Army – despite its staff reduction process by 10% over the next 10 years – created AGITEC, a novel Military Organization with the important objectives of identify prominent future technologies with the potential to have a central role in Brazil's Defense and Security; promote the culture of innovation; protect the institution's intangible assets, and manage scientific and technological knowledge, particularly within its R&D projects. To that end, investments were made in human resources training and large and sophisticated laboratory and physical infrastructure.

The Defense area requires absolutely all kinds of knowledge. However, no country can remain at the edge, or even at high levels of development, in all areas of human knowledge. Prioritization is imperative, but it needs to be conducted with criteria and caution, taking into account opportunities, needs, the national competence and, fundamentally, the notion of what it is intended to be as a nation. In this regard, the Army has been developing methodologies to support the strategic alignment of forecasted technologies, to support decision making in strategic plannings. Such alignment is carried out by assessing the impact of potential future technologies on the operational capabilities required by the Army in the medium and long term.

Despite the complexity of these tasks, a methodology is under development to identify critical technologies that can be denied or, when imported, create vulnerabilities in military systems.

Therefore, in integrating the facets of technological forecasting, criticality, and strategic alignment, one can provide accurate information to the Brazilian Army decision-makers, for they better position themselves in relation to areas that should be studied in master's and doctoral programs in Brazil and abroad, the research areas and themes that should be incentivized, R&D projects that should be created nationally or in collaboration with other countries, as well as the critical areas that need immediate development by licensing or transferring technologies, often using offset contracts.

Furthermore, in parallel with the technology forecasting work, other tasks aim to map researchers, STIs, startups and national companies with knowledge about technologies and areas targeted by the Brazilian Army, to identify potential joint R&D enterprises. These tasks also involve foreign countries and institutions that have technical conditions of collaborating and accelerating the impending R&D initiative.

The Scientific and Technological Knowledge Management is another area that receives investments from the Army. Currently, tacit knowledge is preponderant, research and development of the strategic projects involve many actors of diverse expertise and are long term. Therefore, the management of critical knowledge and human resources plays a key role. Accordingly, it increases the importance of proposing methods, processes, and procedures to adequately manage the knowledge generated by the Brazilian Army, specifically in the scientific and technological field. This is a challenge that has been faced with an ingenious combination of art and science.

The Brazilian Army structured its Technological Innovation Hub (NIT), whose mission is to protect the intangible assets generated within the Army and to boost the portfolio of these assets, which is very modest, despite the development of sophisticated generic and dual technologies of high value-added. Thus, the Army does not only aligns itself with the Innovation Law but might also contribute to economic growth and job creation by exchanging its core proprietary technologies with external actors.

In addition, based on the scale of level of technological readiness (FRANÇA JUNIOR; GALDINO, 2019), the Army is developing a methodology to promote clear, concise, and objective communication between the various stakeholders of SCTIEx in order to promote trust and collaboration in projects related to the innovation area, thus following a trend observed in other agencies and sectors (AGÊNCIA ESPACIAL BRASILEIRA, 2018; FRANÇA JUNIOR; LAKEMOND; HOLMBERG, 2017; INNOVAIR, 2016; ROCHA, 2017; STRAUB, 2015).

5 Public Policy Proposals for the Innovation Sector

There are several obstacles to be overcome so that Brazil can become prominent in the field of Innovation. In addition to the aspects presented, the continental dimension, the great physiographic diversity, regional inequalities, and national competence should be considered important conditions in planning and studies to develop policies focused on innovation. Promoting innovation in a country with these characteristics is even more challenging.

However, it is necessary to define what Brazil intends to be as a nation and conduct strategic studies to prioritize the actions to be triggered to make the desired future a reality. Consequently, in order to define the National Innovation Policy (NIP), here are some important issues that, in addition to those presented before, particularly in Section 2, need to be discussed:

- What is desired related to innovation: to short the technological gap by following the path of pioneers, or advance the knowledge frontier in emergent areas with potential future and aligned with the national competence?

- How to identify strategic areas, technologies with potential future and how to be an important global actor in the medium term in these areas?

- What are the most promising international partnerships and cooperations in the fields of Science, Technology, and Innovation?

- How to measure the technological advancement of the country in strategic areas?

- How to prevent the escape of talents, repatriate Brazilian researchers, and attract foreign researchers to Brazil?

- Given the scarcity of resources, globalization of markets, knowledge and competition, what areas should Brazil focus on in terms of innovation (considering its virtues and capabilities)?

- How to align initiatives between the three dimensions of the Triple Helix?

- How to address the long-term issue in an era in which changes are intense, unpredictable, volatile, and complex?

- How to promote partnerships between the various S&T entities?

- How to disseminate and provide transparency to initiatives, enabling the mass participation of society in projects of public interest?

- How to eliminate "feuds" in each of the three "helixes," driving initiatives so they have strategic value for the country and fostering collaboration between such components?

- How to exploit the knowledge generated in universities in favor of the economic growth and social development of Brazil?

- How to ensure the continuation and realization of State policies?

- How to promote scientific and technological development as a mission?

- How to increase resources for investments in Science, Technology, and Innovation allocated for the ministries, in particular the Ministry of Defense?

- How to involve citizens and the private sector in fostering technological innovation?

- How to increase Brazil's life quality through technological innovation?

- How to improve the innovation culture and, with that, enhance the Triple Helix interaction, aiming to boost the innovation process?

- How to promote clear, concise, and objective communication between diverse stakeholders of the NIS so that trust and collaboration are fostered?

As discussed in the previous sections, many of these issues were addressed and overcame by other countries. In addition, some proposals are being implemented by the Army to solve the SCTIEx problems that are partially similar to the Brazilian NIS. Below, there are discussions on topics that should be discussed in the course of the preparation of the NIP.

a) Prioritization of investments in R,D&I

The examples of success extracted from the international community show that it is necessary to prioritize investments on innovation based on a well-established strategy that considers the actual needs and capabilities of the country, focusing efforts and resources on clear and specific objectives in certain sectors that have the potential to leverage the economy (CORREA FILHO et al., 2013).

The dispersion of financial resources with investment in various sectors, as occurs in Brazil (DE NEGRI, 2018), may be attractive from a political point of view, but it is inadequate for economic growth, since in order to leverage a given sector that is relevant to the economy it is necessary to concentrate resources (MONTEIRO, 2018). Accordingly, it is essential to map the sectors that have the potential to become the drivers of the country's economic development, especially those of high technology that adds substantial value and require a higher labor´s specialization, as they may provide larger returns on investments and better wages (FERNANDES, 2007 apud MONTEIRO, 2019a).

Thus, developing technology forecasting methods to identify potential technologies for the future and consistent with national demands is crucial. It is expected that the new products developed by these technology-intensive sectors will trigger the emergence of related supplier activities and service providers involving advanced technologies, leading the development of other sectors, a fact that expands economic activities in which the country can operate, enabling the internalization of technologies and fostering research and development focused on innovation.

It is acknowledged that the development of high-tech sectors may provide an advantage for the country to be actively introduced into the geopolitical and international economic scene. Prioritizing government investments, concentrating resources on strategic sectors that are capable to control sensitive technologies with great potential to generate innovation, can bring changes to the NIS. Such innovations have the potential to generate new materials, products, and services, creating areas of economic activity that

will result in organizational changes in Brazilian companies and their relations with the market (MONTEIRO, 2019a).

These strategic sectors need to be selected based on the versatility of technologies in order to impact as many sectors as possible so that the innovations generated become a bedrock of the national reindustrialization. A good NIP needs to keep the focus on the economic aspect, prioritizing what can effectively generate a new product or service with commercial value, regardless of the personal desires of groups that see Science as an end in itself.

b) Strengthening the Brazilian National Innovation System

Section 2 shows that the Brazilian NIS presents numerous deficiencies that need to be dealt with. These deficiencies involve all pillars of the Global Innovation Index, so they transcend aspects related only to the field of science and technology and should be treated holistically. Above all, it is necessary that the market demands innovation. Therefore, related initiatives should be triggered by the ministries, whose strategic policies and actions should be complementary and coordinated. For example, to increase the supply of engineers is inefficient if there is no market to absorb them; to increase the number of patents is inefficient if they are not negotiated; or to share public laboratory infrastructure is inefficient in an environment where legal uncertainty prevails. It is essential to develop the innovation culture, seeking to expand the interaction and integration between all actors of the Innovation System, focusing on certain values, beliefs, and behavior patterns (AZEVEDO, 2017, 2018).

Despite the broad nature of the topic, particular attention should point to institutions involved with generation and appropriation of knowledge, as well as to the links between these institutions (ZHANG; CHEN; FU, 2019).

The deficiencies in the research, development, and innovation processes result in organizations having difficulties in appropriating the innovation, given its scarce internal mechanisms for identification and consolidation of knowledge, protection, and exploitation of technologies and innovations created. Failures, gaps, and antinomies need to be solved in procedures and specific legal standards that provide protection to the innovation-oriented research and development process in the country. Efficient appropriation of immaterial assets and the adoption of proactive measures that meet opportunities for improvement in the research, development, and innovation process are of particular importance for the effectiveness of the NIP, as they represent a source of revenue for investments in Scientific and Technological Institutions and an important differential for the development of the national industry, due to the possibility of ensuring the economic advantages arising from intellectual property (MONTEIRO, 2018).

In order to improve Triple Helix mechanisms, academia, industry, and the government need, together, to discuss the NIP direction. The Triple Helix model has been used by several countries to trigger the emergence of centers for technological innovation and technology transfer, business incubators, new laws, and new funding mechanisms. However, in Brazil, the interaction between research institutions and companies is limited

to points of contact, as a probable consequence of the late emergence of both research institutions and Brazilian industrialization (SUZIGAN; ALBUQUERQUE, 2008).

In summary, there are several cases of successful initiatives in other countries that need to be analyzed for the construction of a policy adjusted to the national reality. It is essential that public policies are interrelated in order to ensure, in addition to the allocation of financial resources and implementation of tax incentives, the development of infrastructure and skilled human resources that effectively enable innovation. The promotion of technological and innovative development needs to be treated integratively with industrial development; accordingly, it is possible to affirm that the generation of innovation depends on the National Innovation Policy and on the National Industrial Policy, consistently prepared and implemented aimed at upholding the industry.

c) Efficient Government Technology Procurement

The Legal Framework for Science, Technology, and Innovation represented a paradigm shift regarding public procurements for Research, Development, and Innovation. This was an important initiative to stimulate innovation and technological development because the State has been an innovation protagonist in the main economies of the world, and an efficient and effective legal framework enables safe and swift contracting of companies and institutions dedicated to this need. However, despite recent efforts, difficulties remain for full utilization of the technology procurement mechanism (MONTEIRO, 2019b).

Hence, it is relevant to analyze the American experience, which created a whole legal framework for this purpose through the United States of America Federal Acquisition Regulation (FAR). The FAR is introduced in title 48, chapter 1, of the United States Federal Regulation Code. Each U.S. federal department can supplement the FAR according to the nature of its executive agencies. The U.S. legislation aims to deliver swiftly, the best value product or service to the customer, maintaining the public trust, and meeting the policy objectives (FAR section 1,102[a]).

The FAR comprises the recognition of the U.S. government that certain acquisitions are influenced by subjectivity and the economic and social impact, such as those focused on research, development, and innovation. Consequently, the FAR suggests, in several parts, that the acquisition price should not be the only element to be considered, but also an appropriate approach to the issue of technological development and innovation needs to be taken into account. Because it recognizes the importance of technological development, this regulation treats differently the acquisition processes involving risk, high complexity, and information asymmetry. Thus, the State's relationship with private suppliers in R&D acquisitions is faced as a "partnership" and not merely as a usual contract. Moreover, in order to search and interact with the market, the FAR strongly recommends the use of "Request for Information" (FAR, subsection 52,215-3) before making contracts; it also recommends that bidding public notices should be differentiated when technological risk is in place, risen from the nature of the knowledge and technique

involved (RAUEN, 2014). It is recognized that the U.S. legislation inspired the Brazilian S, T&I Legal Framework, however, the former is much more flexible and effective, since the latter still contains the rigidities of previous legislation, the General Tender Law, since it requires that the selection process contains previous and certain criteria concerning the contracted object, with little margin of freedom for the contractor to innovate according to the real needs of the market and according to the perceptions of the risks involved.

d) Improvement in Governance Criteria

In addition to the use of sophisticated tools of market intelligence, technological forecasting, strategic alignment, criticality, and communication mechanisms, to promote governance and innovation management it is essential to develop reliable indicators of innovation. Despite the advances, such as those achieved by GII, there are still many opportunities to improve in this area of research.

The evaluation of the performance of innovation-related policies traditionally focuses on static analyses of innovation inputs and outputs, as occurs, for example, with GII. However, this approach has limitations already pointed by the OECD (Organization for Economic Cooperation and Development), because, despite presenting an important source of information about the content and direction of technological research and development, it is not able to reflect the actual degree of economic productivity and growth occasioned by innovations. This conventional model provides a static framework that does not take into account the dynamics of interrelationships between actors working in the innovation process.

Recent models seek to highlight the importance of interactions or links between the people and the institutions that integrate the NIS and, therefore, are involved with innovation. Accordingly, it is necessary to establish procedures for data gathering about knowledge flows that occur between institutions during the innovation process and to map innovation environments to identify those involved and their Interrelationships. The OECD has already taken the initiative to develop new types of innovation flow indicators, including statistically human resource mobility, knowledge dissemination, and the classification of innovative companies.

Adequate innovation policies need to emphasize the role of joint research activities and technical collaborations between companies and public institutions. Thus, incentives and suitable legal frameworks that enable and promote partnerships related to research of critical technologies with government participation are of great value. Therefore, an efficient policy will seek to foster innovation networks and design information flows, links, and partnerships efficiently.

Finally, the integration and coordination of public policies with impacts on innovative processes, use of conventional indicators and knowledge flow indicators, mapping of national innovation environments, tools for technology prospection and market intelligence, strategic alignment, and criticality constitute an important framework to conduct the management and governance of the NIS.

6 Final Considerations

Motivated by the poor performance indices of the Brazilian NIS, this article addressed the phenomena of innovation, particularly on topics that should be widely discussed to support the development of a comprehensive NIP, as the issue requires.

It was clear that the Sectoral Innovation System of the Defense Sector is inseparable from the Brazilian NIS. Science and Technology were prominent as a necessary condition to boost the national innovation environment.

The long-term nature of the accumulation of technological capabilities was emphasized, especially in developing countries that don't have control over critical technologies such as Brazil. Thus, it was emphasized that the NIP embraces long-term strategic actions.

A brief diagnosis of the Brazilian NIS was presented evidencing the main bottlenecks, which must be addressed holistically and not in isolation, as in the case of several actions undertaken by Brazil over the last few years.

Some similar and successful experiences and practices adopted in countries of diverse cultures and realities were discussed. Hence, it is highlighted the universality of practices such as a solid education dedicated to the areas that leverage science, technology, and innovation and the imperative value of professionals who work in education at all levels.

It was shown that the Army is aware of the issue and since 2009, when it began its transformation process, it has made efforts to increase its capacity for innovation and thus create the means to fulfill its constitutional goals in an increasingly dynamic and uncertain context.

Inspired by established theories and practices, the Army's actions are ongoing, often involving organizational changes, such as the creation of new structures.

More emphasis started to be given to the importance of dual technologies, in order to exchange the knowledge generated internally and with its partners to contribute more effectively to national development; to enhance its modest portfolio of intangible assets; and to create better conditions to increase the participation of the Brazilian society in the Defense area, especially in the field of S, T&I.

It is necessary to highlight that the Army has made efforts to increase its competence in technological forecasting and strategic alignment fields. Therefore, it seeks to prioritize its strategic actions, its human capital, and its financial resources, identifying, still in the phase of initiation and growth of the technology life cycle, those with potential for the future and that may greatly impact the operational capabilities required by the Army in the medium and long term.

It was presented some central questions, which answers can support the design of Brazil's NIP. Finally, it was discussed some proposals to be included in the NIP, such as the strengthening of Brazil's NIS, the efficient use of the government technology procurement resource, the improvement in governance criteria, and the prioritization of investments focused on R,D&I.

Investments in forecasting and strategic planning tools, as well as the definition of goals and objectives, focused on potential areas for the future, are increasingly important. Medium and long-term planning becomes crucial to reverse Brazil's poor performance on innovation, moving it to a position compatible with its physiographic and economic potential, especially in core areas of the Fourth Industrial Revolution. The often unsuccessful attempt to shorten the "technological gap," especially in areas belonging to the Industrial Era, must be reviewed.

Brazil is a country of great opportunities, endowed with many resources that need to be exploited in a sustainable way, and full of talented individuals in various areas of knowledge that need to be properly mapped, supported, and employed.

In addition to being one of the largest markets in the world, Brazil has numerous competencies, one of the largest biodiversities and abundance of mineral and natural resources, which generates a wide range of possibilities for innovation. Brazil is not located in regions marked by the main worldwide tensions, there are no separatist movements, and, despite the continental dimensions and regional specificities, the same language and strong cultural ties are shared. There are sophisticated innovation environments in the South and Southeast of Brazil, not forgetting that the national deficiencies can be transformed into great opportunities.

In order to be prominent in the field of science, technology, and innovation, it deems necessary to rely on highly qualified human capital, at all levels; to have a state-of-the-art research infrastructure; to have a sound, consistent and unbureaucratic regulatory environment that fosters long term and risky private investments; to comply with agreements, contracts, and laws; to have an agile intellectual property system that guarantees investment returns; and to have a market structure that incetivize competition without protectionism. Nevertheless, is essential to have basic education with quality to shape instructed citizens and demanding customers. This will boost the innovation market and create the conditions to start a virtuous circle.

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