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INNOVATION IN THE DEFENSE SECTOR: A SYSTEMIC PERSPECTIVE

Marcelo Araujo Basto
Department of Science and Technology of the Brazilian Army (DCT)
basto.marcelo@eb.mil.br

Jorge Madeira Nogueira
Department of Economics at the University of Brasilia (UnB)
jmn0702@unb.br

Fábio Cordeiro de Lima
Department of Engineering at the Univerity of Brasilia (UnB)
fabiolisboa@unb.br

Tercio Brum
Army General Staff – Science, Technology and Innovation Section (EME)
brum.tercio@eb.mil.br

Abstract. *The evolution of the Brazilian defense sector, which has taken place in recent decades, has raised awareness of the need to have an integrated, coordinated innovation system that is compatible with the desire to maintain the country's national sovereignty. The objective of this work was to understand how the dynamics of the defense sector influence the management of innovation, in terms of the interactions between the actors of its innovation system. The method was structured in the approach of theoretical development of the deductive type, due to the fact that it starts from theoretical foundations pre-established in the literature, by the conceptual aspects of the Sectorial System of Defense Innovation (SSI Def), from a mixture of two theories, presented by Malerba (2004) and Muñoz and Encinar (2014). Based on a cross-sectional time horizon, the content analysis method was used on the data collected, both in the 14 (fourteen) semi-structured interviews carried out with key actors in the innovative defense process, and in the bibliographical research carried out. Among other findings, evidence of little connection between SSI defense agents was verified. Despite this, the sectorial system of Brazilian defense innovation demonstrates that it is following its evolutionary path, mainly due to the intentionality of the agents involved.*
Keywords: *sectoral system of innovation; defense sector; interaction; agent.*

1. INTRODUCTION

In terms of the Sectorial System of Innovation (SSI), Malerba (2002) envisaged an ex-ante analysis of the different industrial niches from a multidimensional, integrated and dynamic perspective. To this end, the author uses the concept of "building blocks": the knowledge base and technologies; the actors and generated networks; and institutions; being an important tool for carrying out analyzes and dynamic comparisons between different sectoral systems, as well as identifying the existing boundaries between them.

Innovation is dependent on externalities, such as the influence of suppliers' technological resources; consumer demands; and the knowledge derived from the R&D activity (De Fátima Silva, 2011). Thus, the systematicity inherent to innovation, together with the demand for knowledge, requires a constant interactive effort by companies, respecting their sectoral productive similarities and differences (Edquist, 2001).

Innovations in the context of the defense industry are generated through the interaction between different actors, of which the following stand out: universities, Science and Technology Institutions (ICT), development agencies and the Government itself. From this relationship, technological and non-technological innovations are created, developed and disseminated, through the transfer of resources that enable the establishment of partnerships, cooperation, collaboration, agreements and compensation agreements (Franco-Azevedo, 2013).

It should be noted that evolutionary efficiency occurs in an economic system when the intention of agents is carried out through their actions. This happens when there are efficient connections between agents' actions and their goals, turning intentions into concrete facts and achievable goals (Muñoz and Encinar, 2014).

In this line, this work is based on the premise that the little interaction between actors in the defense sector is caused by barriers inherent to sociocultural and technological aspects that are peculiar to the innovation system of this sector.

This work is justified by the importance of knowing the innovative process within the scope of the national defense sector, to enable its better systematization, especially in relation to the process of promoting innovation It also has to do with the lack of studies in this sense, and with the novelty of the approach taken in this research, based on the theory of (Malerba, 2004; Muñoz and Encinar, 2014).

Thus, the objective of this article is to understand the dynamics of interactions between the actors of a Defense Innovation System. For that, a conceptual approach was carried out following the studies of Malerba (2004), regarding the building blocks, and of Muñoz and Encinar (2014), about the intentionality of the agents. In addition, a survey was carried out of the main peculiarities of the dynamics of the defense sector, and of its current institutional arrangements linked to innovation, in terms of the relationship between its actors.

2. LITERATURE REVIEW

The term "Innovation System" was conceptually proposed by Lundvall (2016), although Friedrich List, in the 19th century, already considered the structure of a "national system of political economy" (List, 1986), when considering the intangible value of investment in innovative-technological activities, linking the economy of a given nation to the result of the accumulation of discoveries and inventions of its ancestors, which, jointly, would constitute the intellectual capital of the human race (Soete and Freeman, 2012).

2.1 Malerba and defense's SSI

To be considered sectoral, an innovation system must present, according to Malerba (2002), the following well-defined aspects: the member companies; the other actors, who go beyond the firm's idea; relationship networks; the dynamics of demand; the various institutions involved; the knowledge generated and applied; and the basic processes of interagency interaction.

In the book "Sectoral Systems of Innovation" (Malerba, 2004), the author not only proposes a three-dimensional structure to evaluate sectoral innovation systems, but also presents the way in which each one relates to the innovation process, the factors that affect innovative activities and the relationship between the innovative performance of companies and countries in different sectors.

Based on the basic theoretical foundation of this work, innovation in a given sector is affected by three groups of variables: knowledge and technologies, actors and network; and institutions, which have a high capacity to influence innovation and technological change, depending on the characteristics of each sector.

For this reason, there is a symbiotic relationship between the institutions, either vertically, involving the Government, or horizontally, between those at the infra-governmental level. For this bias, innovation policies cannot be compared to other public policies for tax incentives, financing and subsidies in general. According to Malerba (2002), the common incentive policies would not be enough to support the innovative process, being a priority and safer to seek first to improve the arrangements of a given sectoral system.

In general, Lamb (2005) establishes that in the context of the Armed Forces, the concept of evolution can be understood as a set of reforms with the aim of increasing the effectiveness of military capabilities, coming to be configured as a "military revolution". in operational art and science".

Differences between institutional arrangements can influence the quality and intensity of interactions between defense SSI actors. Thus, knowledge and learning are NIS paradigms that require decisions, for example, regarding the priority of resources to be invested in the development of priority technologies (Fagerberg, 2004; Lundvall, 2016).

Systems integration involves skills in solving both social and technical problems. In the social aspect, the most common problems refer to the lack of communication or the imprecision of the communication that travels between the actors involved, resulting from the existing differences in work methods and routine and, also, due to the inequality in the organizational cultures of each actor (Mota, 2009).

The organization's culture, added to the specificities of the defense market's technological standards, directly influence the sector's demand, which requires alignment with the doctrinal foundations and strategic aspects, which are always evolving, making it difficult to interconnect this sector with the SNI (Dombrowski and Gholz, 2006).

One of the main characteristics of the defense economy is the occurrence of monopsony and monopoly, given that the State is, in many cases, the only demander and buyer of war production, and which promotes low competitiveness in a small number of companies branch (Leske, 2015). The natural consequence of this specificity is the reciprocal dependence of these entities.

Malerba (2004) considers the relevance of the demand, due to the exogenous occurrence of its function. Unlike what conventional economic theory usually considers, from the perspective of defense SSI, the demand is stipulated by the State, in addition to having heterogeneous agents in its innovative process.

2.2 The intentionality of innovation agents

Muñoz and Encinar (2014) raise the issue of the intentionality and capabilities of agents in building the structure and performance of an IS, proposing a criterion of evolutionary efficiency. In general terms, intentionality would be the characteristic of representations about something or directed at something that is linked to objectives, activating: the development of capacities; the testing of new connections within a system; and the generation of new knowledge.

Aligned with this issue, Squeff (2016) states that, in order to become innovative, strong and able to compete in the market, a defense subsystem and its actors need to be aligned with the national objectives stipulated for the sector, and support its infrastructure scientific and technological.

Intentionality refers to the ability of agents (individuals or groups) to have beliefs, objectives and intentions that guide their behavior and influence the environment in which they are inserted. In the cognitive sciences, intentionality is seen as a fundamental characteristic of the human mind and is studied in areas such as psychology, cognitive neuroscience and philosophy of mind.

The argument that agent intentionality, as a necessary condition for a substantive explanation of the dynamism of economic systems, is consistent with the role of intentionality categories in cognitive science, artificial intelligence, and social philosophy (Muñoz and Encinar, 2014).

The constitution of evolutionary capabilities by agents within an Innovation System allows for a two-layer analysis. On the one hand, it is possible to analyze the constitutive elements of the system, such as the agents (companies, universities, governments, etc.) and the connections between them (eg. partnerships, collaborations, knowledge transfer), that is, its structure. On the other hand, it is possible to analyze how the connections between these elements evolve, that is, their dynamics.

In this criterion of evolutionary efficiency, the evaluation of success is not based only on final results, but on the ability of the system and its agents to adapt, learn and evolve over time. This means that success is not measured only by a momentary achievement, but rather by the system's ability to keep in constant evolution (Muñoz and Encinar, 2014).

Thus, the evolutionary efficiency criterion takes into account not only efficiency in terms of productivity and performance, but also the ability to adapt, learn and innovate, which are fundamental for the continuous evolution of a complex system. He values the process of self-transformation and the continuous search for improvements, instead of focusing only on immediate results.

3. RESEARCH METHOD

The CIMO method (Context; Intervention; Mechanism and Outcome) was chosen to help formulate the question of this work, as it is the most suitable for research in the area of Social Sciences. This decision was based on the dimensions provided for in that method, and collaborated with the question of this research.

Starting from the presented research question, for a first approximation to the theoretical framework, a search was carried out in the main collection of the Web of Science (WoS) repository base, considered one of the most used databases in the academic field, for having a considerable supply of quality scientific journals (ZHU; LIU, 2020).

For establishing the design, Sounders et al. (2016) brought the concept of research onion to organize and order the sequence that a study focused on applied Social Sciences, as is the case of the present work, should obey. Through this concept, it is possible to justify and give robustness to the methodological decisions that occurred throughout the research, having been implemented in this work, as illustrated in Figure 1.

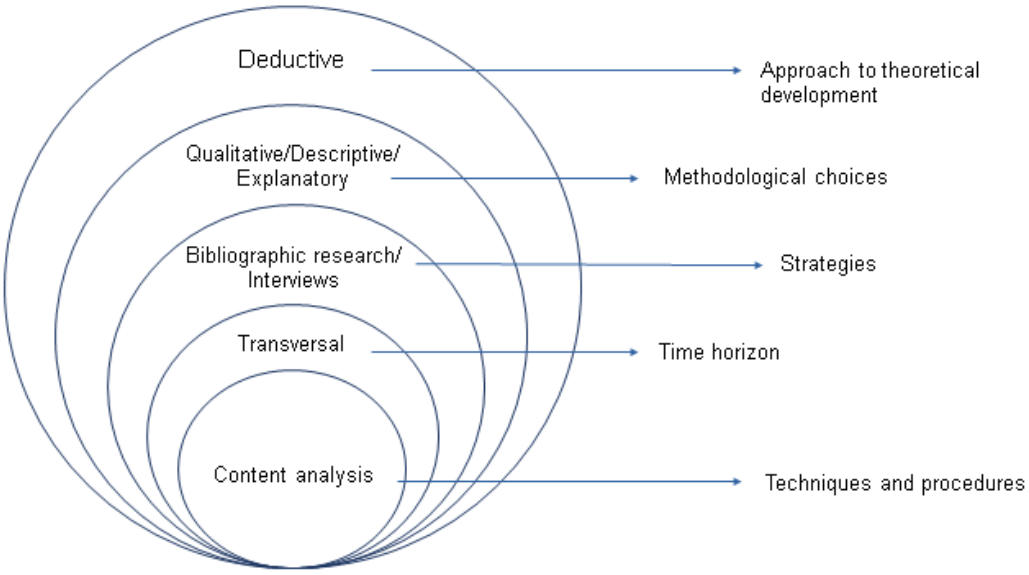

Figure 1. Survey design

Taking into account the fact that the performance of senior management professionals, as well as the involvement of leaders, is indispensable for the consolidation of innovation systems (Alpkan et al., 2010), it was decided to select respondents through intentional sampling, that occurs when the choice of participants is made non-statistically, based mainly on the participants' supposed in-depth knowledge of the topic actors linked directly or indirectly to the innovation process.

The interviews took place, in person and by videoconference, in a heterogeneous sample, used when the intention is to obtain different readings on the same topic (Minayo, 2010), which included 14 professionals in positions with decision-making power and influence over the innovation process in the defense sector.

4. RESULTS AND DISCUSSIONS

4.1 Bibliographic search data analysis

The interagent relationship, within the innovation ecosystem of the defense sector, proved to be marked by multiple opportunities, such as the diversity of technologies developed to meet the operational combat capability of military units.

However, the heterogeneity of the agents involved and the existence of certain characteristics of the technological regime, such as the asymmetry of information and differentiated demand, tend to harm this interaction.

Still in this line, conservatism, predominant in the defense sectors (Franco-Azevedo, 2013), may harm the interaction between agents linked to innovation, because, when seeking to preserve the community identity of the military branch (Tamayo; Schwartz, 1993, p.331-332; Schwartz, 1994), involuntarily, ends up closing the system for the civil branch and for the other sectors.

Conservatism tends to negatively impact the innovation process. This aspect is related to customs and practices inherent to communities, making it essential for their survival. Thus, this conservatism would explain the use of customs that preserve the identity (Schwartz, 1994) of the military sector.

Among the peculiarities involving the defense sector, which can influence the relationship between the agents of the defense sector focused on the innovation of the three Forces, the issue is highlighted: differentiated demand; and the top-down organizational structure (Franco-Azevedo, 2013).

One feature of the military career that can impact science and technology systems is personnel turnover. However, when it comes to CT&I, this can generate important mishaps such as: delays in schedules, discontinuations or stoppages in RD&I projects; emergence of technological gaps; and discredit of development agencies.

In this line, Franco-Azevedo (2013) calls the "Ocelot Complex" a peculiarity of the Armed Forces, which conditions the military career to a constant process of change, which, according to that author, has a strong potential to promote the discontinuity of activities related to innovation.

Innovations in the context of the defense industry are generated through the interaction between different actors, of which the following stand out: universities, science and technology institutions, development agencies and the Government itself. From this relationship, technological and non-technological innovations are created, developed and disseminated, through the transfer of resources that make different forms of cooperation possible (Franco-Azevedo, 2013).

For Malerba (2004), the issue involving how new actors are created is a relevant aspect to explore the dynamics of sectoral innovation systems. In this sense, the defense has two examples: AGITEC and SisDIA, which are structures created to identify and meet the technological demands of the present and future of the Land Force, with a vocation to minimize the technological gap in the country, as well as to reduce the distances in relation to the academy's activities (Oliveira Junior, 2019).
In his work, Oliveira Junior (2019) compares, maintaining due proportion, AGITEC to the North American DARPA, to get an idea of the relevance of that Agency for the Brazilian defense sector, especially for the Army.

4.2 Analysis of interview data

Based on the characterization of the sample, it is possible to verify that the majority of the actors of the SSI of defense interviewed occupy the current position for less than two years, from which, initially, it can be inferred that there is an indication of high turnover of these functions, and that this, consequently, can interfere with the maturation of the system's innovation processes.

From the responses and spontaneous testimonies of the interviewees, it was possible to perceive that, in general, there is a coincidence in terms of interest in pooling efforts aimed at the innovative development of the defense sector. This is clear in the initiatives revealed and in the underlying intention in the speeches of these agents, in relation to the need to abbreviate the connections between them.

Another relevant fact was the notion demonstrated by agents outside the military branch of the defense sector, regarding the objectives pursued by the three Forces. Despite this, the Ministry of Defense declared, mainly by agents linked to the promotion of innovation, severe difficulties in making its technological priorities explicit.

When evaluating the areas of technological interest, one can see the existence of several opportunities for internal and external cooperation in the defense sector, both within each Force and between them. The various partnerships that could be the result of interactions between this ICTMD and the aforementioned bodies could lead to the development of innovative products, for example: prototyping real problems from a quantum simulator; ultra-fast processing from a quantum computer; of superconductors; of ultra precision sensors; of encryption equipment; of atomic clocks; processing strategic situations, simulations and energy modeling of molecules and reactions; medical diagnostics, research and simulation in quantum bacteria, among others.

The topic "bureaucracy" was constantly mentioned by the interviewees as a relevant factor that has harmed the interaction between the agents, which converges with what has already been shown in this work, by the statements of Pirró et al. (2011).

In this way, the research pointed to the existence of a chronic bureaucracy that is mainly reflected in the procedures related to obtaining credit aimed at R&D in the defense sector. This is aggravated by the high heterogeneity among agents, given the

multiplicity of interactions in terms, for example, of meeting demand and the dynamics of financing innovation, both in the firm and non-firm segments.

Likewise, a Interviewee claimed that: "...within the system, decision-making happens less quickly than project-based management requires... there is greater rigidity and hierarchization among managers, and the need to having to follow military doctrines", which confirms the difficulty perceived by entities in the civil branch, external to the defense sector.

The resistance to change characteristic of the defense sector is linked to the tendency to adhere to closed innovation models, contrary to what Chesbrough (2006) proposes, which considers the adoption of open innovation essential for the effective improvement of the innovative capacity of the various systems.

One of the evaluative factors Franco-Azevedo (2013), of the inducing type, most cited by the interviewees, was the occurrence of esprit de corps, and to some extent corporatism within the Armed Forces.

5. DISCUSSIONS

Complementarity is one of the topics highlighted by Malerba (2004) It refers to the dynamic interactions between different products, processes, technologies and activities in an economic or industrial system. These interactions can occur due to interdependencies and feedback between different elements of the system, leading to a series of mutual benefits.

The interviews made clear a generalized dissatisfaction among the actors of the system in relation to the difficulty in defining the priority technologies to be developed for defense. This fact may be generated by the sector's specific demands and also by the decentralization of actions that, in theory, would fall to the MD.

The differentiated demand from the defense sector is largely caused by the fact that the Government is the main, and in some cases the only, demander of technologies and products. In addition, there is dependence on military doctrine and constantly evolving strategic aspects that need to be considered.

The intentionality and evolutionary capacity, proposed by Muñoz and Encinar (2014), became the agenda of this research so that a more in-depth analysis could be carried out, allowing the transparency of intangible aspects of extreme importance for the understanding of a sectoral innovation system, starting from what had already been raised based on the concepts of (Malerba, 2004).

The ability of the defense sectoral system to evolve can be impacted by its organizational structure and dynamics. The hierarchical nature of military institutions, based on a top-down structure, tends to stiffen decisions inside and outside the sector and to promote departmentalization and centralization of actions aimed at innovation.

Based on the "intentionality" variable captured by the interviews, the agents' commitment and willingness to contribute to increasing the synergy of their relationships was verified. This was made explicit in the different initiatives of the MD, the MCTI, the ICT, and educational institutions, civil and military, to promote the development of technologies of interest to the Forces.

However, the occurrence of failures in communication was noticed, which may be a consequence, for example: of the peculiar language of each of the three Forces; of the peculiar tendency to ostracize institutions of the military branch; and the lack of knowledge, on the part of civil agents, of the peculiarities of the defense sector, such as doctrinal issues linked to the demand.

In the case of the culture internalized in military organizations, several aspects tend to harm interagency relationships, such as: the characteristic conservatism of military institutions; and the constant change of personnel in decision-making positions, which have the potential to negatively impact interaction within the defense innovation system.

In addition, during the interviews, the observation that the dispersion of initiatives scattered throughout the military branch of the innovation system also jeopardized the definition of priority technologies was recurrent, which can be explained by factors such as: the lack of effective centralization of decisions at the level of the Ministry of Defense, and dependence on financial funds from innovation promotion agencies.

Finally, the reliability between agents, which, according to Muñoz and Encinar (2014), is highly relevant in the synergy of an innovation system, proved to need special attention when it involves the defense sector, given the existence of aspects such as: uncertainty in relation to government purchases and public policies to encourage industry; and recurring budget irregularities.

It is possible to deduce, from what was researched, and based on Malerba (2004) and Muñoz and Encinar (2014), that sectoral systems of defense innovation have a natural vocation for the induction and dissemination of knowledge. However, they are dependent on regularity in the budget, on good interaction with development agencies, on an effective relationship with the academic environment.

In Brazil, the fact that there are several financing agencies dedicated to funding the MD's technological demands undermines the governance and dynamism of the financing process. DARPA, for example, is one of the most famous models in the world in terms of convergence of decisions on defense technologies (Mazzucato, 2014).

Table 1 consolidates the context categories, the categories of analysis used in this work, pointing out the main aspects raised, based on the data collected throughout the research.

Table 1. Content Analysis Categories.

Context category	Analysis category	Aspects raised
Actors and networks	Identification of new compositions	Creation of new financing modalities for defense
		Inserting new agents in the system
	Relationship	Multiplicity of interactions
		Articulation difficulty
		Heterogeneity among actors
Technological regime	Complementarity	Dual feature of technologies
		Complementary technologies and areas of interest
		Technological diversity among agents
	Accumulation of capabilities	Low incidence of patent registrations
		Low absorptive capacity
	Availability of information	High information asymmetry, especially in relation to highly complex dual technologies
		Tendency towards low reliability among agents
	Demand	Differentiated (Government monopsony power)
		Difficulty setting priorities
		National security as a priority objective
		Difficulty in prioritizing
		Dependence on military doctrine
		Dependence on constantly evolving strategic aspects
Evolutionary capacity	Organizational structure	Hierarchical (top-down)
		departmentalized
		Centralization of functions
	Industry dynamics	Consciousness of the agents in the search for mutual benefits
		High ability to learn
		Growing ability to adapt to changes
		Existence of different products, processes, technologies and activities in an economic or industrial system
Intentionality	Commitment	Growing agent initiatives
		Approach to the academy
	Communicability	Recurring communication failures
		Ignorance of the defense sector
	Trust between actors	Unpredictability present in business involving defense
		Monopsonic market
		Mutual dependency between agents
		Complex regulatory environment with a heavy tax burden
		Uncertainties regarding government purchases
		Uncertainties regarding public policies to encourage industry
		Budget irregularity
	Organizational culture	Conservatism
		Staff turnover
		High bureaucracy

6. CONCLUSIONS

This study showed that agents belonging to the defense sector interact based on the peculiarities of the Armed Forces. Traditionally, the characteristic aspects involving agents in this sector greatly influence the dynamics of innovation systems.

The present research confirmed the symbiotic relationship between the technological regime and the forms of relationship between the actors, pointed out by Malerba (2004). The wide variety of priority defense technologies, which develop at different levels of technological readiness, added to the potential interactions between defense innovation agents reveals the diversified nature of the sector. On the other hand, this would also indicate the existence of a promising path of systemic maturation, in the medium and long terms, marked by complementarities between its actors.

The predictability and continuity of the demand for technological development must be at the heart of innovative defense processes, and depend greatly on an effective dialogue between the actors involved, in order to produce a relationship network capable of guaranteeing the continuity of the sector's strategic projects and the articulation of mechanisms to promote the industrial base.

Aspects such as: the need for budgetary continuity, lack of confidence, low communicability, and the peculiarities existing in the defense sector, indicate a tendency towards obstacles in terms of the relationship between agents belonging to the innovation systems of this sector.

In short, it was possible to observe a tendency towards low connectivity between the actors belonging to the defense innovation systems, which may result in delays in their evolutionary capacity, and consequently, come to harm the dissuasive power of the countries.

Finally, it is understood that the methodological and theoretical perspectives, proposed by Malerba (2004) and Muñoz and Encinar (2014), and followed in this research, enabled the achievement of the proposed objectives. The vision from the building blocks, and the agents' intentionality concepts, allowed the understanding of aspects linked to the interactions of the actors of the defense innovation sectoral system, and how they can interfere in the evolution of this system.

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8. RESPONSIBILITY NOTICE

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