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DEFENSE IN THE PERSPECTIVE OF THE ECONOMIC AND INNOVATION THEORIES

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ABSTRACT

This paper contextualizes empirical studies on the effects of military spending and military R&D on economic growth, scientific and technological development, and industrial performance in the light of economic theories. For this purpose, we present the theoretical assumptions underlying classical, neoclassical and heterodox economic approaches, highlighting how innovation has taken on a central role, to proceed with outlining the effects of military spending raised in the literature. We then examine the econometric models, concluding with the proposal of a new classification that explicitly explains their relationship with their supporting economic paradigms aiming to contribute to the interpretation of their results.
Keywords: Defense. Economic Theories. Scientific and Technological Development and Innovation.

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INTRODUCTION

In the last quarter of the 18th century, Adam Smith stated in his work, which would mark modern economic thought, that "... the great object of the political economy of every country is to increase the riches and power of that country" (SMITH, 2010, p. 351). The theoretical thinking of the 17th and 18th centuries clearly established the relationship between power and wealth, considering them "the joint objectives of national politics, each reinforcing and promoting the other" (VINER, 1948, p. 15). During this period, Whiston (2012, p. 3) noted the impact of the introduction of large-scale firearms in wars, which became more of a financial endeavor than the employment of men. "[...] success goes with those who can spend more money for a longer time" (WHISTON, 2012, p. 3).

For Sombart (1913), war was an important instrument in the rise of modern capitalism because, despite the negative effects of a protracted conflict, such as waste of resources, loss of labor and instability of trade, war would bring externalities such as stimulating production and innovation, organizational changes and social mobilization. Dagnino (2010) describes how civilian companies have explored advances in military R&D in commercial applications since the 1950s, also benefiting from the effects of economies of scale, leading to known innovations such as computers, semiconductors, and airplane turbines. These technologies outperformed – in cost-effective terms – the technologies that had been developed before the war effort.

Likewise, Momayezi (2006) mentions theorists that think that government arms procurement by developing countries would also be an attempt to boost local industry by attracting investment, stimulating competitiveness, fostering jobs and promoting transfer of knowledge.

In the national context, the literature on defense industry (DI) and scientific and technological development has been growing (FONSECA, 2000; DUARTE, 2012; LONGO & MOREIRA, 2013; SQUEFF, 2014; SOUZA,2015; SILVA, 2015; ROSENDO & PEDONE, 2016; BORELLI & PERON, 2016; AMARANTE & FRANKO, 2017), reflecting the political context that has included on the agenda the military transformation, restructuring of the defense industry, and technological autonomy, revitalizing the association between defense and development. Nevertheless, the current economic crisis has brought budget cuts and contingencies that threaten to compromise these initiatives (SILVA, 2016).

This article aims to contextualize empirical studies on the impact of defense, especially military R&D, on economic growth and on scientific and technological development in the light of economic theories. For such, we pay a quick visit to the different economic paradigms. A second part is devoted to outlining the possible effects, positive and negative, of so-called military spending on the economy and on scientific and technological development. A third part presents a synthesis and classification of empirical studies on the theme in a survey elaborated for the thesis on which this article is based. Then we make brief concluding remarks.

BRIEF COMPENDIUM OF ECONOMIC THEORIES

CLASSIC ECONOMIC APPROACHES

In classical economic approaches, it is believed that economics tends to equilibrium, having the "Say's Law" as one of the pillars. Briefly, Say (1865) argued that "it is production which opens a demand for products." Money's whole utility has consisted in:

> [...] conveying to your hands the value of the commodities, which your costumer has sold, for the purpose of buying again from you; and the very next purchase you make, it will again convey to a third person the value of the products you may have sold to others (SAY, 1855, p. 137).

According to the author, it is necessary to sell first to be able to buy. Aggregate demand is considered equal to aggregate supply. If individuals produce for the purpose of purchasing, income (production) not used in present consumption will be destined for future consumption. In other words, it is necessary first to save before investing. Thus, in classical theories, saving equals investment in an ex ante perspective, not implying a reduction in demand; however, it would be essential to reduce consumption to increase savings.

Keynes (1978), however, defined this equivalence between savings and investment from an ex post perspective, where income obtained through investment generates savings. The economist proposed that the enrichment of a country is not given by the negative act of individuals not spending all their income, but by the positive act of using these savings to increase the capital stock. The British then created the concept of effective demand (consumption plus investment). The retention of monetary values for hoarding implies, for Keynes, that this balance is not invested in capital goods, negatively impacting production, which reduces income and, consequently, consumption, inhibiting subsequent supply and, therefore, jobs. Thus, unemployment would be a result of insufficient demand for goods and services in the economy. That is, demand would determine supply.

Mathematically, the Keynesian model can be represented by:

$$Y = C + I + G + (X - M)$$

- Where Y is the national income;
- C is the consumption
- I corresponds to the investment
- G to public spending
- X is total exports
- M are the imports so that
- (X–M) represents the external sector net demand.

Thus, the state could stimulate economic growth (increasing income) through incentives for consumption, investment and increased government spending (except for tax increases because it would discourage consumption).

An increase in public spending (which would include government investment) would have a multiplier effect, as an increase in an individual's income increases their marginal propensity to consume (percentage that one person spends for each extra unit of income). Consumption of this individual in turn increases the income of other individuals in a geometric progression cascading effect. The return on investment would then be proportionally higher than the initial investment. "When there is an increment of aggregate investment, income will increase by an amount which is k times the increment of investment" (KEYNES, 1936, p. 115).

The multiplier offers one:

> [...] explanation of how fluctuations in the amount of investment, which form a comparatively small proportion of the national income, are capable of generating fluctuations in aggregate employment and incomes so much greater in amplitude than themselves (KEYNES, 1936, p. 122).

NEOCLASSICAL ECONOMIC APPROACHES

The neoclassical explanation for long-term economic growth was based primarily on the formal economy models developed by Robert Solow in the late 1950s. According to this theorist, economic growth results from the capital accumulation, labor and technological progress, the first two being the factors of production, and the last would be the exogenous factor to the accumulation of wealth. This relationship between factors of production and income tends to strike a balance: capital is accumulated through savings (considered equivalent to investment), but the level of capital per worker decreases with their depreciation and population growth.

The increasing capital application to a given trend of population growth results in diminishing marginal productivity, also known as the "law of diminishing marginal returns" or "law of diminishing returns." In other words, each increase in capital generates less impact on yields with the long-term zero yield trend.

As a result, the economy reaches a state where, in the absence of technological progress, capital per worker remains constant and economic growth ceases to give way to the so-called steady-state. The process by which a country continues to grow despite diminishing marginal returns is exogenous and occurs through the creation of new technologies that allow productivity increase with the same resource endowment.

Following this reasoning, the richest countries (developed countries) would have a slower economic performance while the developing countries would grow faster. Over time, the diffusion of capital, technology, and *know-how*[2] from developed to developing countries would make

[2] The set of human and physical capital, legal system, institutions, tacit knowledge necessary to produce a good collectively at the corporate level constitute know-how (ABDON et al., 2010). Tacit knowledge refers to the intangible knowledge imbued in each individual, the personal knowledge that each individual carries, what they observe and learn from experience and which is internalized and therefore not readily available for

them converge at the same stage of development (ROSTOW, 1980). Thus, the persistent gap between "rich" and "poor" countries remains unsolved inside this paradigm. A recurring criticism of the neoclassical approach is that technology is understood as an exogenous factor for economic growth and as a public good whose access is free to any company anywhere in the world. What is observed, however, is the presence of economies of scale, imperfect competition and appropriation, at least temporary, of technologies.

THE ROLE OF SCIENCE, TECHNOLOGY AND INNOVATION AND NEW ECONOMIC THEORIES

Romer (1986, 1990) sought to circumvent this contradiction by explaining permanent growth through the accumulation of knowledge, which would constitute a form of capital upon which the law of diminishing returns does not operate, so it can be accumulated unlimitedly. Moreover, knowledge is unrivaled, that is, its use by different companies or individuals does not reduce its availability and is not exhaustible with use (there is no depreciation). Moreover, knowledge cannot be considered totally excludable, as it provides externalities that drive the growth process.

Economic theories, such as the New Growth Theory, the New Economic Geography, the New Trade Theory, and the Evolutionary Theory of Economic Change, then emerged to fill gaps in mainstream or orthodox thinking.

In Schumpeter's (1934) thinking, innovation was already seen as the driving force of development. Development would take place through a dynamic process in which new technologies would replace previous ones in what the economist called "creative destruction." Companies holding new technologies would benefit from a temporary monopoly in which they could act as *price-makers* (that can determine prices) rather than *price-takers* (that can only accept established prices), allowing much higher profits. As new knowledge diffuses among other firms (imitators or rivals), comparative advantage ceases and returns to perfect competition until the cycle begins again.

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transfer (MURALIDHAR, 2000). According to Chugh (2013), it is the skills, ideas and experiences that people have in their minds that are therefore difficult to access as they often cannot be easily expressed or formalized. This knowledge is reflected in human actions and their interactions with the social environment (DELONG & FAHEY, 2000 apud CHUGH, 2015)

The Schumpeterian perspective has gained new breath with the works of Nelson and Winter (1982) and Dosi (1984), which initiate evolutionary or neo-Schumpeterian approaches. Possas et al. (2001, p. 334, our translation) summarize the main theoretical axes of evolutionary theory:

> "Behavioral *diversity* among agents, [which] is endogenously generated by a process of *seeking* innovation opportunities; the *selection* of companies, strategies and/or technologies from a dynamic based on competition and continuous change, without any reference to balance" (emphasis in original).

In criticism of traditional economic theories, Eliasson (2010) pondered the role of tacit knowledge. For the Swedish economist, in these theories there is no distinction between knowledge and information, seeing knowledge as mere accumulated information, ignoring the difficulties of communication and the transfer of tacit knowledge. Tacit knowledge – the one that is difficult to express, formalize or share (SVEIBY, 1997) – is what restricts the process of economic development. "Ultimately, differences in prosperity are related to the amount of tacit knowledge that societies hold" (HAUSMANN, 2011, p. 16).

Gilpin (2001, p. 107) reviews heterodox approaches and how they address the role of technology:

> These new theories allow the inclusion of technology or knowledge as a [third] factor of production. The growth rates of national economies, the pattern of international trade and the very structure of the international economy is increasingly dependent on a country's capacity for technological innovation. [this] in turn resulted in the high interest of all governments to technologically strengthen their economies and stimulated 'techno-nationalism': government efforts to prevent the diffusion of their most important technologies. Competition among national economies for technological superiority has become an important feature of international political economy.

The preponderant role of technology for economic development is recognized even in the very definition of the term, characterized by Troster and Mochón (2002, p. 333) as the "growth process of an economy, along which new technologies are applied and they produce social transformations, which entails a better distribution of wealth and income." Economic growth would then be, according to the authors, "an aspect of another more general process: the development of a society that causes, over time, fundamental changes in its organization and institutions" (TROSTER; MOCHÓN, 2002, p. 333).

Amaro (2003) highlights the influence of international context on the emergence of the concept of post-WWII development. The postwar period was marked by the process of European reconstruction, aiming to resume "its paths of progress and wealth, that is, of development" (AMARO, 2003, p. 4, our translation). The confrontation situation during the Cold War demanded the formation of a base of productive accumulation that sustained the arms race and the scientific and technological race, connecting scientific and technological innovation to progress. In conjunction with the adoption of Keynes's ideas about state intervention in the economy, unlike earlier currents that advocated the self-regulating role of the market, the state came to be seen as a determining agent in achieving progress and growth. "From the mid-twentieth century, science and technology (S&T) became a central part of the national policies and strategies of the most developed countries" (LONGO; MOREIRA, 2013).

Arrighi and Drangel (1986) observed, between 1938 and 1983, a tendency to concentrate wealth in the hands of a small number of states, which represented only about 15% of the world's population. In contrast, there was a concentration of poverty in a group of countries corresponding to 60%. The remaining 25% lived in States that were in an intermediate position between the so-called "poles of poverty and abundance" (ARRIGHI; DRANGEL, 1986, p. 43 apud ARRIGHI, 1998).

Similar percentages for the concentration of technological innovations were raised by Sachs (2000). A part of the planet representing only 15% of the world's population would be the source of most technological innovations. A second set of countries, covering about half of the population, were able to adopt these technologies in the production and consumption spheres. The remaining portion, comprising one third of the population, would be living technologically marginalized: without domestic innovations or adoption of external technologies.

Evidence that the existence of clubs of convergence of per capita income levels would be a result of differences in technological capacity – supporting the Schumpeterian perception of the preponderant role of innovation – has been pointed out by several recent studies, such as

Nakajima (2003), Howitt and Mayerfoulkes (2002) and Castellacci and Archibugi (2008). These authors identified three groups of countries:

- The advanced or developed countries, drivers of the innovation activity;

- Intermediate countries, which are capable of imitating and reproducing foreign technologies;

- Latecomers, which are unable to innovate or imitate.

In a similar approximation of classification, Krause (1992, p. 26-33) divided countries into three levels according to their defense industries.

At the first level, the author framed the "critical innovators," the weapon producers whose capabilities lie on the technological frontier of war production (US and USSR/Russia). At the second level are countries that adapt and modify advanced military technologies (most of Western Europe), the third includes the rest of the countries, which can only copy and reproduce defense technologies.

Bitzinger (2009) qualified the three levels differently. Although the first coincides in definition with that pointed out by Krause (1992), for that author, besides the USA at this level would be the four largest European producers (United Kingdom, France, Germany and Italy). According to Bitzinger (2009), the second includes a variety of countries: (a) industrialized countries with a small but sophisticated defense industry (Australia, Canada, Sweden, etc.); (b) developing or newly industrialized countries with a modest defense industry (Argentina, Brazil, South Africa, etc.); (c) developing countries with a large, broad-based, defense industry, but still without independent R&D and industrial capacity for the production and development of highly sophisticated conventional weapons (India). Countries with a very limited defense industry production capacity and low technological intensity are at the last level.

DEFENSE AND ECONOMIC EFFECTS

Smith and Smith (1980) described ways in which military spending could influence economic growth by listing positive and negative aspects:

• Resource allocation and mobilization: opportunity cost and crowding out (*displacement or avoidance of private investment*), diverging investment resources and other welfare expenditures of the population on the one hand. On the other hand, defense can be used to improve infrastructure, mobilize resources and create demand, boosting the economy.

• Organization of production: a large war sector can have a modernizing effect with respect to training and organization. It can also create a bubble effect, an industry dissociated from the economic needs.

• Socio-political structure: the military can be worker resistance and modernization. On the other hand, a military government can be an economic disaster.

• International Relations: military spending may provide greater security, impose international respect and promote development. But it can also encourage conflict (arms race) and lead to dependence on financial aid because of imbalances in the balance of payments.

Peled (2001) also highlighted the various channels through which military spending can affect development: (a) increased security, which increases social welfare; (b) defense allocations can increase total productivity of productive factors by training a highly skilled workforce, building infrastructure, increasing technical progress through R&D, and encouraging spin-offs; (c) opportunity cost or crowding out; and (d) diverting brains from civilian to defense sectors.

Dunne et al. (2005) summarized the effects of military spending on supply, demand and security.

Effects on supply operate through the availability of the production and technology factors that determine production according to the neoclassics. Dunne et al. (2005) cited the possible difference of military mobilization from production factors through compulsory recruitment of "ideological fervor," especially in the presence of security threats. However, in the perception of these authors, the resources mobilized are used for military purposes, making them unavailable for civil use. Supply-side effects also account for externalities such as the effect of military training, which can increase the labor factor productivity, increasing labor force qualification through military training (whose impact is reflected on the rest of the economy when workers migrate to civil sectors).

For its turn, the effects of demand may include, considering orthodox economic assumptions, opportunity costs, and crowding out of private investment and consumption. The form and extent of crowding out depends on how the increase in public spending is financed: through cuts in other public spending, tax increases, borrowing or expansion of the money supply. Changes in government investment may also change the composition of economic resources (production factors), with effects on the trade output.

We emphasize that, according to Ram (1995 apud FRANKO, 2003), military spending would be essentially non-productive, since a missile is not edible, nor can it be used to manufacture other goods. However, part of these expenditures may go towards building infrastructure (focusing on improved productivity) and paying wages and pensions (stimulating demand).

Security effects derive from the stability necessary for the operation of markets. In the face of external and domestic threats, security encourages investment and innovation. As defense spending increases security, it can also increase productivity. However, it can also lead to an arms race, and even to a conflict.

INFLUENCES OF INNOVATION AND MILITARY R&D ON SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT

Specifically referring to innovation, Mowery (2010 p. 1238) analyzed how military R&D and procurement can influence scientific and technological development:

• Military funding for new bodies of scientific or engineering knowledge that promote innovation in civil and defense applications.

• Spin-offs, where military R&D programs produce technologies with civil and military applications. Spin-offs occur most significantly in the early stages of new technology development, as these stages present a substantial overlap between defense- and civilian-related applications. Depending on the nature of the technology, there is a greater difference between civil and military use and the benefits of spin-off are reduced.

• Defense contracts can affect R&D investment by defense industry companies, directly and indirectly affecting the development of new technologies. The channels of interaction between spin-off and procurements are more significant when the requirements of new civil and military technologies are undermined. As a consequence, influence of military R&D and procurements decline as technology matures.

Schwam-Baird (2006) listed several motivations for developing countries to pursue the so-called "military industrialization": 1) insertion into a hostile security environment in which the reliability of the arms supply is a security need; 2) political considerations, such as the desire to reduce dependence on external suppliers, as well as the potential use of arms sales as a political instrument or a way to increase national prestige; 3) Advocates of military industrialization are confident in the promise that such development programs will serve as engines of general industrialization, technology acquisition, and economic development; 4) intrinsic economic objectives, which are the gains that could come from the profitable arms market.

It is important to emphasize that the industrial process of military material production is complex, with multiple intervening factors, such as the total level of industrialization, the existence of an adequate economic infrastructure, well-qualified workers, links with other industries to supply materials, as well as product marketing, some degree of state support and protection and the existence of internal and external markets that absorb production (ACDA, 1997).

Ruttan (2006) investigated the role of military R&D and defense procurement as sources of commercial technology development for six generic technology sectors: aeronautics, nuclear energy, computing, semiconductors, internet, space communication, and terrestrial observation industries (satellites). According to the author, these technologies have had a pervasive impact on a wide range of US industries through radical or revolutionary innovations. In addition, they brought important spin-offs, such as the microwave, derived from research for radar development.

Nevertheless, measurable effects of positive externalities only appear when these generic technologies approach the stage of maturity, in which there is some stability with few advances (RUTTAN, 2006). An example of this is electricity. The first commercial system for the production and distribution of electric power appeared in 1878, but it was not until the 1920s that it began to gain prominence in the growth of industrial productivity. From the early 1920s to the late 50s, the electric power industry was the source of nearly half of productivity growth in the United States. However, to maintain productivity growth rates in this virtuous circle, according to Ruttan (2006), development of new technologies for generic use is necessary. These are responsible for high growth rates and their permeability potential of different industries (hence the generic term) promotes breakthroughs in multiple civil sectors.

In the case of the six general technologies, which emerged as essential factors in growth in the US in the second half of the 20th century, their researches have shown that military and defense demands played a key role in rapidly reducing their learning curves. However, such results do not extend to other developed countries. In a study with OECD member countries, a 10% increase in military spending led to a rise in technological progress of only 0.5% (DUNNE et al., 2005). More specifically in relation to industrial sectors directly linked to the production of weapons, such as metallurgy, electrical machinery and transportation, the direct impact of military spending on the output of each industry was negative (KELLY & RISHI, 2003).

Ruttan (2006) has raised strong criticism of the performance in civilian appropriation of R&D efforts, considering that US initiatives to support the creation and diffusion of commercial technologies, except in the areas of agriculture and health, have failed to achieve economic and political viability. For the theorist, however, there is no alternative in these cases to investment in military R&D, as private enterprise cannot replace military enterprise in the development of new general technologies. This is because, in early stages, while new technologies are radically different from current technologies, the gain from these advances is diffuse and difficult to capture by leading companies in their development. Thus, private companies would have weak incentives to invest in R&D. For the technologies analyzed in Ruttan's work, it took several decades of public and/or private support to reach the threshold of commercial viability.

The progress of nuclear power illustrates this argument. Its theory was well advanced in the 1930s, but there was no practical progress due to the lack of overly expensive laboratories. The Manhattan Project, during World War II, responsible for the production of the first atomic bombs, allowed the "allocation of resources for the creation of large laboratories at the Stanford, Princeton and Harvard universities, the coordination between physicists and engineers and with those and the highest level of political and military decision makers in the United States" (WALTON, 2005).

PUBLIC INVESTMENT AND DEVELOPMENT

Defense investment can be taken more generally as a type of public investment. Econometric studies attest to a significant and positive impact of government investment on income levels, directly and indirectly. Directly,

> [...] through the change in income caused by a change in public capital and [indirectly] through the positive effect of the increase in public capital on the marginal productivity of private inputs (labor and capital) (REIS, 2007).

For example, public investment in infrastructure such as energy, transportation, and communication systems can increase productivity and hence the profitability of private investments, producing a crowding in effect (REIS, 2007). Lichtenberg (1995) identified a positive impact of government financing: a U$1 increase in government sales meant a 9.3 cents increase in private R&D investment, while a U$1 increase in non-government sales only impacted R&D investment by 1.7 cents (LICHTENBERG, 1995). A similar relationship is found for government-funded and civil R&D. Several empirical works confirm the positive, albeit discrete, effect of public funding (BRONWYN; REENEN, 2000; DAVID; BRONWYN, 2000; LACH, 2002; GUELLEC; van POTTELSBERGHE, 2001). Slavtchev and Wiederhold (2012) find a positive effect on increased public procurement in the high-tech industry by providing higher profit expectations for innovative companies, generating incentives for firms to invest in R&D.

On the role of public investment, Rossetti (1977) investigated what he calls the "sword and plow dilemma." This dilemma builds on the assumptions of the frontier of production possibilities and reflects an opportunity cost, establishing a trade-off relationship between security (swords) and welfare (plows), also known as the cannon or butter dilemma.

> In symbolic language, the production of swords on a large scale leads [...] to reduced possibilities for producing plows. [...] if the option falls on plows, the resources available for sword production will certainly be reduced (ROSSETTI, 1977, p. 155).

In other words, there would be an opportunity cost in allocating productive resources for defense. Campos (1963) stressed how this dichotomy would be especially true with the greater presence of high technology and industrial participation in the military power:

> The root of the conflict is that the composition of resources most conducive to the goal of power is not exactly, at least in the short term, the one leading most directly to wealth and a high standard of living. On the contrary, power, having its direct manifestation as force, implies the accumulation of nonproductive capital, while wealth rests on the accumulation of productive capital. If we remember that the National Product consists of two parts, consumption and investment, it is intuitive that the accumulation of power instruments implies either the subtraction of consumption, immediately reducing the standard of living, or the reduction of the share of productive investments, compromising the future capacity to produce goods and services (CAMPOS, 1963 apud ROSSETTI, 1977, p. 155).

An alternative solution to this dilemma can be found in Franko (2003). For the author, innovations (technological progress) allow the frontier of production possibilities to shift so as to make it possible to release resources to produce more butter without necessarily reducing cannon production or increasing cannon production without sacrificing butter production.

The use of procurements to foster innovation has been addressed in recent works (SQUEFF, 2014; OECD, 2015; Edquist et al., 2015). Through their purchasing power, governments could shape innovation directly, helping companies recover the high and risky R&D costs, and indirectly, as the primary consumer, the government has the ability to influence the diffusion of an innovation.

EMPIRICAL STUDIES ON THE RELATIONSHIP BETWEEN DEFENSE AND ECONOMIC GROWTH

Initiatives to ground economic theoretical considerations in empirical studies were ultimately undertaken to describe the relationship between defense, economic growth, and scientific and technological development. This section is based on the analysis of 81 previous works that use empirical data to assess the impact of defense spending on economic growth, industry performance, investment or scientific and technological development.

It is worth mentioning Mowery's (2010) caveat about the difficulties, with the lack of publicly available data, in parameterizing how to measure the specific technological results of military R&D, the impact of these advances on the performance of civil and military products, and the characteristics of the benefits of spillovers outside the defense sector.

In a simple organization of the empirical studies surveyed according to their conclusions, there is no consensus on the subject, as shown in Figure 1 below:

Figure 1

Figure 1 – Survey of empirical studies on the relationship between defense and growth. Own elaboration.

About 36% of the results indicated negative effects, a proportion highlighted in red on the above graph. The yellow area represents studies that found negative and positive effects that cancel each other out or found no correlation, 12 of 81 studies or 14.81%. The blue area shows the proportion of authors who identified some kind of nonlinear defense-growth relationship, with no apparent pattern or positive impact to a certain extent, reverting to a negative relationship after this threshold, varying over time and countries studied. The green area includes the results that identified positive impacts, 22.22%. Represented by the gray area are the researches that investigated the direction of the causal relationship, obtaining varied results: income-defense direction, defense-income direction and two-way relationship. A more detailed description of this survey can be found in Serrão (2015).

According to Hou (2010), the econometric literature on the relationship between economic growth and defense can be divided into seven categories: works with statistical analysis such as Benoit (1973, 1978), precursor of the studies reviewed here; supply-side models (Feder type models); demand side models; Deger type models (include supply side and demand side); Solow models (neoclassical theory of economic growth), Barro model and Granger causality test (in which the causal direction is analyzed).From the survey summarized in Figure 1, it was decided to formulate a new classification of such empirical models according to the paradigms adopted in its construction: neoclassical paradigm of economic growth, heterodox economic approaches and statistical analysis of growth indicators (whose insertion in either growth paradigm varies depending on the indicators chosen). It is important to highlight that the classification of statistical analyses, particularly, has less defined boundaries, and there are also techniques that combine more than one classification.

Quadro 1 - Classificação de estudos empíricos sobre defesa e crescimento econômico. Elaboração própria.

Abordagens econômicas neoclássicas	Modelos tipo Feder (oferta)	
	Modelos tipo Deger (oferta e demanda)	
	Modelos tipo Solow (crescimento exógeno)	
Abordagens econômicas heterodoxas	Modelos keynesianos	
	Modelos de crescimento endógeno	
Análise estatística	Modelos lineares	Regressão linear[3]
		Modelos de efeitos fixos
		Modelos de efeitos aleatórios
	Modelos não lineares[4]	
	Análise de correlação	
	Análise multivariada	
	Meta-análise[5]	
	Direção causal	Teste de causalidade de Granger (linear e não linear)
		Modelos autorregressivos
		Métodos mistos[6]

[3] Regression refers to a set of statistical techniques for estimating the value of a variable according to the values of other variables. In other words, it analyzes the relationship between a dependent variable y and an independent variable x or a set of variables. The relationship can be linear or nonlinear.

[4] Including nonlinear regression methods.

[5] Meta-analysis is a quantitative approach that allows one to synthesize and compare the individual results of a set of studies using statistical tools by using a common metric. For a detailed description and application to Defense Economics studies, see Alptekin & Levine, 2010.

[6] According to Johnson, Onwuegbuzie, and Turner (2007, p. 123), the mixed-method approach is the one in which researches or models combine quantitative and qualitative elements in its stages (for example, in the types of data collected and in the collection instruments themselves, in the analyses, inference techniques, among others) "for a broad and deep purpose of understanding and corroboration." This approach is called triangulation by Denzin (1978). Simply put, it is a combination of different methodologies in the study of the same phenomenon.

From the survey summarized in Figure 1, it was decided to formulate a classification of such empirical models according to the paradigms adopted in its construction: neoclassical paradigm of economic growth, heterodox economic approaches and statistical analysis of growth indicators (whose insertion in either growth paradigm varies depending on the indicators chosen). It is important to highlight that the classification of statistical analyses, particularly, has less defined boundaries, and there are also techniques that combine more than one classification.

The findings of Benoit (1978) and his seminal work – in which he identifies a significant positive effect of the defense on economic growth – inspired other authors (FREDERIKSEN; LOONEY, 1983; BISWAS; RAM, 1986), who unsuccessfully tried to reproduce his results. Ball (1983) points out how Benoit's linear regression results do not point to that correlation, but Benoit interpreted the results, attributing a positive effect based on his personal assessment of the unquantifiable benefits (not found in his study) of defense for growth.

In order to overcome possible methodological problems in Benoit, mathematical models were developed based on neoclassical assumptions to investigate the possibility of displacement or avoidance of resources for defense from other areas (opportunity cost) or displacement of private investment (crowding out effect). However, these studies, from the perspective of demand, already presuppose, a priori, a situation in which defense competes for scarce resources with the private sector or present an opportunity cost for other areas such as health and education. Consequently, they tend to find a negative correlation between defense spending and economic growth.

Most studies on the impact of military R&D are of this type. The main questions addressed are: (1) whether military R&D outcomes can be achieved with other types of public or private R&D, and (2) the extent to which government investment in military R&D discourages or encourages private R&D. For the first question, in the absence of data to compare military R&D outputs and other R&D sources, researchers focused on R&D inputs using the innovation production function created by Griliches (1979).

Supply-side models emerged based on the model proposed by Feder (1983) to measure the effect of exports on economic growth. According to Hou (2009), these models often show a negligible or positive impact of military spending on economic growth, identifying positive externalities, especially in the sense of creating demand for jobs and

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products. Of the 16 works that adopted this approach, six did not identify a causal relationship – or this is insignificant – and six pointed to a positive (but discreet impact for two), confirming Hou's (2009) observation.

In order to solve the debate, models inspired by Deger (1986) were developed to try to capture both the positive effects by stimulating demand and other externalities, and the negative effects of reduced investment and opportunity cost. Despite accounting for both possible positive and negative impacts, most studies conclude that defense has a negative effect on economic growth.

Solow-type models have expanded the neoclassical production function considering that defense can impact the productivity of production factors as it improves the efficiency of each worker through military training , that is, through technological progress of the "work" factor. In the survey for this survey only three works were identified with this explicit model, two of which find negative impact and one finds positive impact.

In the Barro model, military spending is assumed to have a nonlinear effect on economic growth, produced by the interaction between increased productivity and market distortion effects. Multiple variables would affect this relationship, such as the presence of external threats. However, this approach is considered as scarcely flexible in multivariate modeling (DUNNE; SMITH; WILLENBOCKEL, 2005).

Studies aimed at identifying the possible multiplier effect of defense investments often assume Keynesian or endogenous growth assumptions, relating the defense industry's innovative potential to economic growth and scientific and technological progress. Most of these studies, however, find negative impact.

Methods that attempt to gauge causal direction, such as Granger's causality tests, address the simultaneity problem. What a country spends on defense is also determined by its GDP. If it is not possible to determine the causal direction, the hypothesis that richer countries may devote a greater portion of their income to defense cannot be distinguished from the hypothesis that defense spending is a contributing factor to economic prosperity (PELED, 2001). Of the studies surveyed, about one-third identify a two-way relationship, slightly less than one-third, a nonlinear relationship that varies according to income and military spending levels, and the remaining third, with no apparent pattern, varying according to the country.

Statistical analyses reach varied results, with similar numbers of positive, negative and nonlinear results, as well as some that did not identify causal relationship.

The development of new models did not inhibit the use of previous models so that several approaches coincide temporally. The choice of one model or another seems to depend more on the authors' position on economic assumptions.

The conclusions that permeate the works in the area in its first two decades are (RAM, 1995):

- The weight of evidence suggests neither a positive effect nor a negative effect of defense spending on economic growth.

- There is evidence of structural[7] heterogeneity both in time and space, however, without presenting a pattern.

- Different[8] defense proxies achieve different results.

- Evidence supporting a statistically significant quadratic[9] relationship between military spending (x) and economic growth (y) is weak.

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[7] "Initially, there are two identical economies. At one point [...], one of them accelerates its innovation rate, which translates into structural change and productive diversification. Technology gradually diffuses into the system as to emerge a homogeneous (similar levels of labor productivity) and diversified (with numerous productive sectors or branches) economy. In the other economy, the technical progress penetrates very partially and only in the most export-related sectors. The structure that emerges in this context is heterogeneous (important parts of employment remain near subsistence levels) and specialized (minimum density and integration of the productive matrix). This economy will not be able to generate the dynamic momentum needed to spread technical progress and to create jobs in higher productivity activities – which may eventually eliminateheterogeneity. The first economy (homogeneous and diversified) is the Center; the second (heterogeneous and specialized) is the Periphery. The origin of the two structures lies in the different innovation rates and technology diffusion – and behind them, in political and institutional differences" (PORCILE, 2010, pp. 65-66).

[8] Variable used to replace another one difficult to measure. Approach. Indirect measure. When no direct data on a variable is available, a proxy variable can be used as an indirect indicator of what to measure. For example, in the absence of per capita income data for a given city, this piece of information can be inferred from other accessible data such as tax collection data (income or industrial goods tax)Relationship between two variables x and y where the variation of x =y2.

[9] Relationship between two variables x and y where the variation of x =y2.

Production functin indicates the maximum production that can be obtained given a certain amount of production factors and a certain level of technology available. (BEGG, STANLEY & DORNBUSCH, 2002, p. 509). Mathematically, it is expressed by: $Y = A \times f(K, L)$

- Where Y is total output
- K is the capital stock
- L is the labor
- A represents available technology

The function $f(K, L)$ indicates the output obtained given a certain amount of capital and labor. Changes in production that cannot be interpreted by changes in capital and labor inputs are attributed to technological progress. When this occurs, it enables greater production with the same amount of production factors.

These conclusions, however, are not definitive due to a series of methodological difficulties beyond the lack of public domain data. For example, heteroscedasticity, explained below, is characteristic of cross-sectional data, a methodology adopted by most large N or wide M approaches[10]. Heteroscedasticity is when the standard deviation of a variable monitored for a specific time period is not constant

For example, price of meals by age: as people get older, factors such as work experience or higher education affect income level. A higher income level allows for different dining options, it is possible to choose a refined restaurant. However, it does not exclude cheaper meal options, such as fast food, because variables such as personal taste, convenience and available time come into play. The range of options increases, increasing the standard deviation. This feature demands specific modeling techniques.

Growth models (whether economic, defensive, or scientific and technological) present another challenge for time series analysis. Existing statistical tools are suitable for the treatment of stationary series, i.e., when they develop over time at random around a constant average, reflecting some form of stable equilibrium. However, by definition, growth models observe trends (increasing or decreasing), and although there are techniques for transforming non-stationary series into stationary ones (extracting trends, cycles, and noise), the probability of failure is higher.

[10] Large N approaches analyze a large number of cases.

Lee, Lin and Wu (2002) also demonstrated how the cointegration[11] in economic growth models significantly increases the false positive probabilite in Granger causality test, which analises the causal direction.

In a simple organization of the empirical studies based on their conclusions, 35.71% of the studies found negative impact of defense spending on economic growth, industry performance, investment or technological development; 21.43% pointed positive effect; 14.29% identified a nonlinear relationship (with positive effect up to a certain point, reverting to a negative relationship after this threshold) or without apparent pattern, varying according to the period and countries studied; 13.09% did not identify relationship, found insignificant relationship or whose positive and negative effects cancel each other out; and 15.48% devoted themselves to studying the direction of the causal relationship.

FINAL CONSIDERATIONS

The trio "defense-innovation-development" (BORELLI; PERON, 2016) is present in the National Defense guiding documents – PND, END, LBDN. However, the review of empirical studies on the subject highlights the lack of cohesion in the results so as to unambiguously support this association.

As explained above, the results are dependent on the paradigms, theoretical assumptions and indicators adopted in the construction of the models, making it difficult to evaluate their conclusions. Moreover, methodological difficulties inherent in econometric modeling introduce another obstacle in the analysis of their contributions.

Ultimately, efficiency in the economic, administrative, or technological sense should not be confused with combat capability. Judging the need for investments in the defense industry solely for its economic performance or scientific and technological performance is insufficient, as the presence of threats and the strategic and political objectives of a

[11] Economic growth models analyze the behavior of variables over time, that is, they work with time series. When time series are first order integrated (with an integration operation, they reach the unit root), however, a linear combination of them has a smaller order of integration (which implies a root smaller than one), they have a stationary combination and are said to be cointegrated. They are apparently independent, but a linear combination of them is not. This property can be used in some models, however, in models that require independence between variables it can cause spurious correlations, likely to have a false positive on the Granger causality test, which analyzes the causal direction.

country may justify the need to invest in the military R&D sector (DVIR & TISHLER, 2000, p. 19).

It is worth remembering that because of the public good character of national defense, the market alone will hardly meet a nation's defense needs. Therefore, government investment is warranted to ensure the provision of defense, regardless of its relationship to economic growth or innovation.

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