FGV EBAPE

RAP
BRAZILIAN JOURNAL OF PUBLIC ADMINISTRATION

Technological innovation in Brazil: challenges and inputs for public policies

Carlos Ivan Simonsen Leal [1]
Paulo N. Figueiredo [2]

[1] President of the Fundação Getulio Vargas, Rio de Janeiro / RJ – Brazil
[2] Full professor of the Brazilian School of Public and Business Administration at the Fundação Getulio Vargas, Rio de Janeiro / RJ – Brazil

This article offers a brief reflection on the nature of research and development (R&D) investment in Brazil, contributing to advancing the debate on this topic. R&D is one of the bases of innovation and productivity, and since 1999 Brazil has consistently increased investment in this area. However, this effort has yielded limited results, suggesting that supplying sufficient resources must be accompanied by effective implementation strategies.

Keywords: technological development; innovation; economic growth; public policy; Brazil.

Inovação tecnológica no Brasil: desafios e insumos para políticas públicas

Este artigo oferece uma breve reflexão sobre a natureza do investimento em pesquisa e desenvolvimento (P&D) no Brasil. Seu objetivo é proporcionar alguns insumos para avançar no debate sobre esse tema na sociedade brasileira. Desde 1999, o Brasil tem aumentado de maneira consistente o seu investimento em P&D, considerado um dos insumos para inovação e produtividade. Porém, tal esforço tem gerado resultados limitados. Esses resultados limitados não parecem refletir mera insuficiência de investimentos em inovação no Brasil, mas a maneira e a eficácia de sua implementação.

Palavras-chave: desenvolvimento tecnológico; inovação; capacidade tecnológica; crescimento econômico; políticas públicas; Brasil.

Innovación tecnológica en Brasil: desafíos e insumos para las políticas públicas

Este artículo ofrece una breve reflexión sobre la naturaleza de la inversión en investigación y desarrollo (I&D) en Brasil. Su objetivo es brindar algunos insumos para avanzar en el debate sobre este tema en la sociedad brasileña. Desde 1999, Brasil ha aumentado constantemente su inversión en I&D, considerada uno de los insumos para la innovación y la productividad. Sin embargo, tal esfuerzo ha dado resultados limitados. Dichos resultados no parecen reflejar la mera insuficiencia de las inversiones en innovación en Brasil, sino la forma y efectividad de su implementación.

Palabras clave: desarrollo tecnológico; innovación; capacidad tecnológica; crecimiento económico; políticas públicas; Brasil.

DOI: http://dx.doi.org/10.1590/0034-761220200583
ISSN: 1982-3134

Article received on June 14, 2020 and accepted for publication on February 06, 2021.
[Translated version] Note: All quotes in English translated by this article's translator.
This is an ongoing study conducted within Fundação Getulio Vargas. Part of this text was presented at the *IV Colóquio de Pesquisa Aplicada da Fundação Getulio Vargas* (colloquium on applied research of Fundação Getulio Vargas) (São Paulo, August 21–22, 2018), at the Brazilian Innovation Agency (Finep, Rio de Janeiro, August 29, 2018), and at an event on innovation and competitiveness promoted by the Federation of Industries of the State of Rio de Janeiro (Firjan) in partnership with the Brazilian Association of Oil Service Companies (Rio de Janeiro, September 24, 2018). This article reflects the ideas and perspectives of the authors and not necessarily those of Fundação Getulio Vargas.

1. INTRODUCTION

The positive impacts of innovation are widely demonstrated throughout history, promoting companies' growth and competitiveness in both developed economies (Audretsch, Coad & Segarra, 2014; Cassiman, Golovko & Matínez-Ros, 2010; Teece, 2014) and developing and emerging economies (Bell & Figueiredo, 2012). Innovation at the company level is vital for countries' economic growth and development (Hall, 2011; Rosenberg, Landau & Mowery, 1992). On the other hand, scarcity of technological innovation capabilities in developing economies represents one of the main obstacles for growth and improving development rates (Dohnert, Crespi & Maffioli, 2017; Lee, 2013; Malerba & Lee, 2020).

In Brazil, it is crucial to accelerate technological development and promote innovation to add value to national production. The country has been paying a high price for its technological backwardness. The export agenda has deteriorated, and Brazil increasingly becomes an exporter of products with low added value. The public sector is expensive, cannot satisfactorily meet society's demands, and lacks efficiency. The service sector generally has low added value and low integration with the industrial sector. These are some examples expressing the national difficulties.

Nevertheless, relevant innovations can be observed in some areas, producing successful cases. Examples are the achievements of the Brazilian Agricultural Research Corporation (Embrapa), the development of oil exploration in ultra-deep waters, the country's technological and commercial leadership in the forestry and cellulose industry, and the history of companies such as Embraer, Vale, Votorantim, Natura, Weg (electric motors), Marcopolo, among others. Also, the achievements in software and medical practice areas stand out, which motivate research and are sources of inspiration. The analysis of these successful experiences offers directions on how the development and diffusion of technologies add value.

In the long term, Brazil's ability to meet its citizens' aspirations will depend on the leverage and diffusion of technological development and innovation. In this sense, either private or public resources must be available and directed according to market demands. Raising funds and investing with an emphasis on technological development is a complex issue that requires understanding potential constraints. It is an issue that evolves with time, and practices are influenced and changed in this process.

Finally, the investment in technological development and innovation must be carried out considering the returns. In this sense, one could argue that Brazil's short and medium-term fiscal conditions and the format of the several structures involved in implementing these investments are insufficient and harm the returns. In addition, it is conceivable to assume that the current situation, from a rational perspective, leads to reduce the national hope of achieving real technological development to a minimum. This article offers a different point of view, opposing these arguments. The discussion in this article focuses on the importance of understanding the challenges of the multifaceted process of technological development and innovation. It is crucial to build an in-depth comprehension of the problem before giving up and accepting arguments based on a potential incapacity of the country to invest in innovation with returns, regaining hope and freedom.

2. STATUS QUO IN BRAZIL

2.1 Aspects of R&D investment in Brazil

The increase in the pace of technological innovation requires focus and investment and is one of the main conditions for Brazil to accelerate its economic growth. However, economic and structural factors reduce the available resources and limit effectiveness. In this context, two problems stand out: the lack of government investments' effectiveness; and the little investment from the private sector, restricted to few large companies.

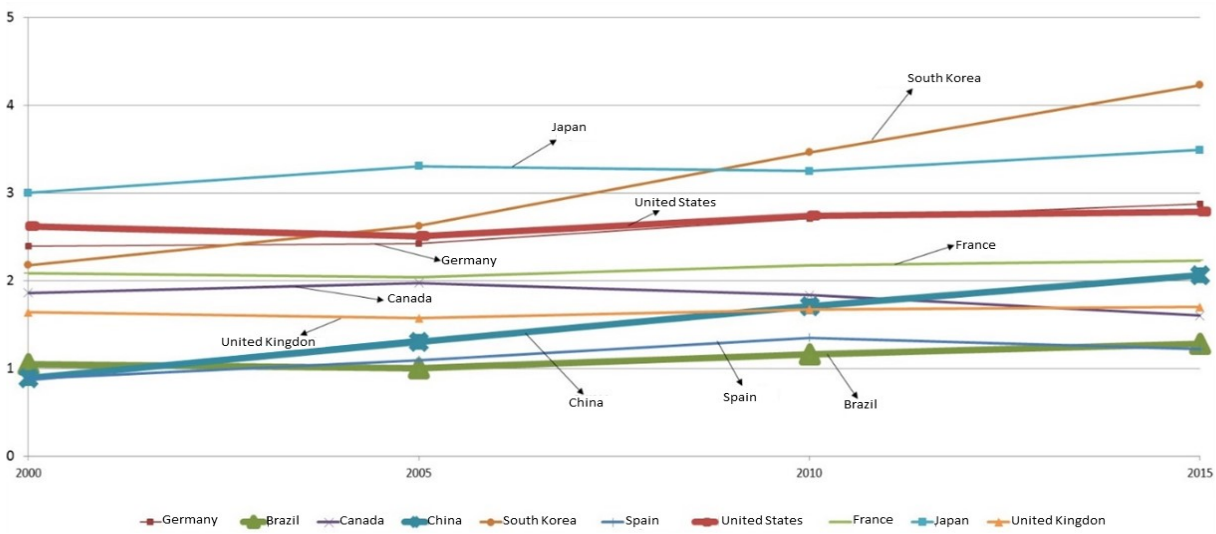
It is well known that the Brazilian government's budget restrictions limit new investments in several strategic areas, including research and development (R&D) – in this case, the maintenance of the current level of investment is already a challenge. This difficulty is associated, among other factors, with legal constraints and with demands the government receives from other sectors of society. Nevertheless, over the past 15 years, this investment has grown and reached levels compatible with nations whose development stage is much higher than Brazils, but the country's results were comparatively smaller. The problem is not simple to understand. Brazil tends to adopt an investment model focused on supplying basic science rather than on technological development. In other words, science is considered a primary source of innovation.

Low private investment is a consequence of the low degree of leverage created as a result of public finances and the excessive degree of oligopolization in the Brazilian economy. The nature of the Brazilian budgetary process prevents creating an effective benchmark for private savings to move in the appropriate way for private investment. This limits the financing of higher-risk activities. Especially affected are the activities of technological development and innovation. Even in the case of local innovations, from simple adoption of an adapted novelty that adds value, which already exists in another part of the world, there are strong reservations.

On the other hand, the well-known phenomenon of excessive oligopolization caused by the tax structure that is excessively dependent on indirect taxes discourages innovation investments. In the short and medium-term, these conditions are unlikely to change. The country can only have a chance to increase its pace of innovation with a better understanding of the expenditures and incentive processes regarding what has to be changed and how.

Without improving the efficiency of R&D expenditures and incentives, Brazil will continue to generate insignificant results in terms of innovation and productivity and, consequently, slow economic growth. Figure 1 shows that Brazil's investment in R&D, as a percentage of gross domestic product (GDP), increased continuously from 2000 to 2015 compared to other countries. Brazil's investment rate in R&D is similar to that of high-income economies, such as Spain (1.2%) and Italy (1.3%), and not so far from that observed in Canada (1.6%).

FIGURE 1 NATIONAL EXPENDITURES IN R&D IN RELATION TO GDP IN SELECTED COUNTRIES (2000-2015)



Source: Ministério da Ciência, Tecnologia e Inovações (MCTIC) (Brazilian Ministry of Science, Technology and Innovation) and Organisation for Economic Co-operation and Development (OECD).

Over the past few years, and especially between 2017 and 2018, Brazil has positioned itself among the ten economies with the largest R&D investments in absolute values (Table 1)[1]. The fact is that, contrary to popular belief, Brazil's effort in terms of investment in R&D is far from being considered insufficient, taking into account its level of development.

TABLE 1 INVESTMENT IN R&D PER COUNTRY (ABSOLUTE VALUES)

Countries		2017			2018			2019		
		GDP PPP Bil. USD	R&D as % GDP	GERD PPP Bil. USD	GDP PPP Bil. USD	R&D as % GDP	GERD PPP Bil. USD	GDP PPP Bil. USD	R&D as % GDP	GERD PPP Bil. USD
1	United States	19,360	2.83	537.59	19,921	2.84	565.76	20,459	2.84	581.03
2	China	23,120	1.96	444.82	24,646	1.97	485.53	26,223	1.98	519.22
3	Japan	5,405	3.50	185.53	5,470	3.50	191.45	5,519	3.50	193.17
4	Germany	4,150	2.84	114.84	4,254	2.84	120.81	4,339	2.84	123.22
5	India	9,447	0.84	76.91	10,146	0.85	86.24	10,938	0.86	94.06
6	South Korea	2,027	4.30	85.43	2,088	4.32	90.19	2,148	4.35	93.46
7	France	2,826	2.25	62.13	2,885	2.25	64.92	2,943	2.25	66.22
8	Russia	2,826	1.52	57.81	4,068	1.52	61.83	4,129	1.50	61.94

Continue

[1] See R&D Magazine, retrieved from www.rdmag.com

Countries		2017			2018			2019		
		GDP PPP Bil. USD	R&D as % GDP	GERD PPP Bil. USD	GDP PPP Bil. USD	R&D as % GDP	GERD PPP Bil. USD	GDP PPP Bil. USD	R&D as % GDP	GERD PPP Bil. USD
9	UK	4,000	1.73	49.16	2,926	1.72	50.33	2,970	1.73	51.38
10	Brazil	2,880	1.18	37.14	3,293	1.17	38.53	3,375	1.16	39.15
11	Canada	3,219	1.80	30.85	1,801	1.80	32.42	1,837	1.80	33.07
12	Australia	1,764	2.34	28.64	1,272	2.34	29.77	1,312	2.35	30.82
13	Taiwan	1,235	2.45	28.20	1,197	2.45	29.33	1,221	2.46	30.04
14	Italy	2,307	1.26	28.39	2,342	1.27	29.74	2,365	1.26	29.80
15	Spain	1,769	1.26	21.81	1,819	1.26	22.91	1,859	1.25	23.23
16	Turkey	2,133	0.90	18.34	2,227	0.90	20.04	2,316	0.89	20.61
17	Netherlands	915	2.10	18.64	945	2.10	19.83	967	2.10	20.31
18	Sweden	522	3.31	16.93	535	3.33	17.82	547	3.28	17.94
19	Switzerland	517	2.98	14.99	529	2.98	15.75	539	2.97	16.01
20	Singapore	514	2.62	13.19	529	2.62	13.85	543	2.64	14.33

Source: R&D Magazine (2019).

As mentioned before, although Brazil's investments in R&D has been increasing over the past several years, the results in terms of innovation and increased productivity are not as significant, which can be verified by the following facts:

1) In the Global Innovation Index (GII), with a ranking of 129 countries, Brazil fell from 47th position in 2011 to 66th in 2018. This is a publication by Cornell University, in association with INSEAD and the World Intellectual Property Organization (WIPO) – www.globalinnovationindex.org. The IGI is based on 79 indicators to calculate four innovation measures. The innovation effectiveness rate measures how much of a result (innovation) a country achieves in relation to its resources, such as investments in R&D. Along with related aggregate indexes, this one has some limitations of a substantive and methodological nature. However, it is useful to obtain an initial basis for measuring Brazil's innovative performance.
2) In the Global Competitiveness Report (2018-2019), Brazil occupied the 72nd position among 140 countries, regressing three positions in relation to 2017 (World Economic Forum, 2019).
3) In the IBGE Innovation Survey (Pintec, 2012-2014), innovative activities in the researched companies are predominantly new. Less than 2% carry out innovations with a degree of novelty new for the Brazilian market, and an even smaller portion implements innovations for the world market (Instituto Brasileiro de Geografia e Estatística [IBGE], 2014).[2]
4) Regarding the increase in productivity, Brazil occupies one of the worst positions among countries with a similar degree of development (Confederação Nacional da Indústria [CNI], 2018; Feenstra, Inklaar & Timmer, 2015).

[2] The Industrial and Technological Innovation Survey (PINTEC) is conducted every three years. It analyzes the sectors of industry, services, electricity, and gas. PINTEC's last edition worked on a sample of approximately 130,000 companies.

These indicators reflect and contribute to the impact of *per capita* income in Brazil. For more than 50 years, Brazil has been static in the condition of a middle-income country, as illustrated in Figure 2. Under this condition, a country has high production costs that prevent it from competing with export-oriented and competitive economies. However, their technological capacity for innovation is not high enough to face competition from companies in advanced economies (Lee, 2013). It is possible to escape this "middle income -and technology trap," as we will discuss in section 5.

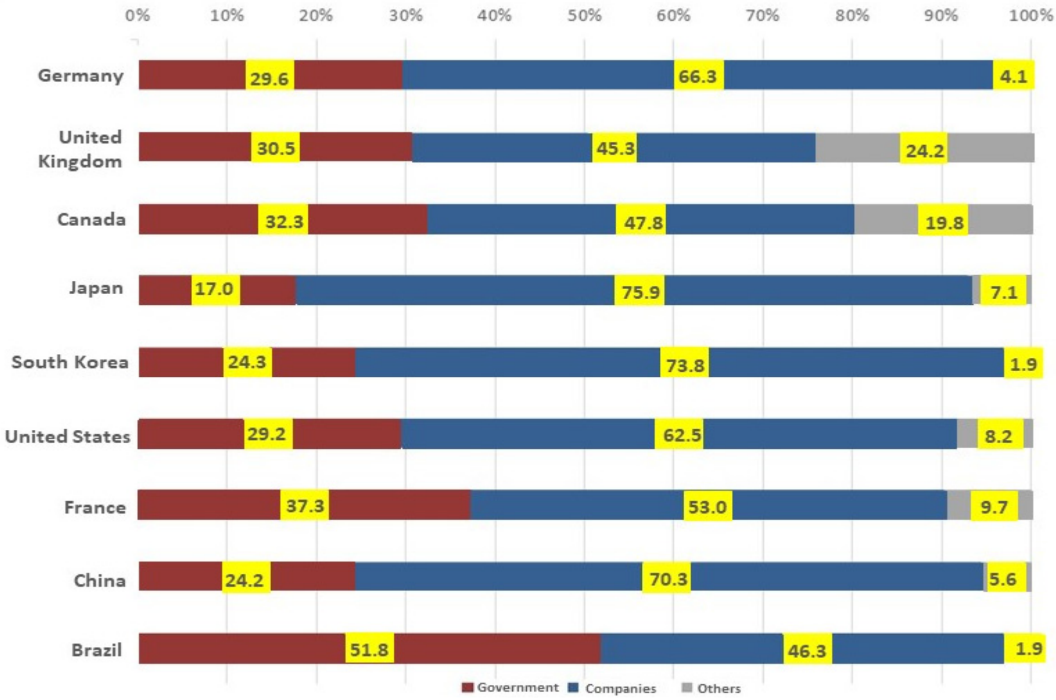
FIGURE 2 BRAZIL: IMPRISONED IN THE "MIDDLE-INCOME TECHNOLOGY TRAP"

Source: Elaborated by the authors.

2.2 How can this paradoxical situation be interpreted?

Among the various factors that have contributed to the indicators mentioned above, the limited presence of the private sector in investments in R&D stands out. Figure 3 shows that Brazil has had the largest state participation in the national R&D effort. This used to be the situation in some emerging economies, such as South Korea and other Southeast Asian economies, in the 1970s and 1980s, and China, until the 1990s. However, these countries reversed this proportion of government participation in R&D expenditures in the following decades, achieving the standards observed in advanced economies. A common feature of high-income countries, including South Korea, but also China, is that companies participate much more than governments in the national R&D effort.

FIGURE 3 **PERCENTAGE DISTRIBUTION OF NATIONAL EXPENDITURES IN R&D, PER FUNDING SOURCES, IN SELECTED COUNTRIES (2000-2015)**



Note: The item "others" includes higher education institutions and nonprofit organizations.
Source: MCTIC (Brazil) and OECD (www.stats.oecd.org).

However, in the Brazilian context, it is important to mention that the percentage distribution of R&D expenditures in the state of São Paulo differs substantially from that prevalent in Brazil. About 60% of R&D expenditures in the state are made by companies. Therefore, the nature of R&D expenditures in São Paulo is in line with that of advanced economies and Asian countries, such as Korea and China. [3]

Brazil's situation, however, has remained unchanged since 2000. This is similar to the average of the other Latin American countries. Finally, the Brazilian scenario is against most advanced economies and, especially, that of Asian countries, such as South Korea and China. In these countries, business investment in R&D was increasing in the period 2000-2015 and higher than government investment. They have gradually created conditions of greater credibility for the financing base for risky investments.

Private investment in R&D guarantees meeting the demands, focusing on results and aims for technological development and innovation. Investors are companies that accumulate experience and specific and idiosyncratic knowledge on technical aspects of products, processes, services, and sales. Furthermore, innovations at the company level and its network of partners in various sectors

[3] See www.fapesp.br (Indicators of ST&I in the Brazilian State of São Paulo, several years).

of the economy are the basis for countries' productivity and growth. As widely demonstrated in the literature, companies that innovate and are more effective achieve better competitive performance and long-term growth (see, for example, Bell & Figueiredo, 2012; Fagerberg, Mowery & Nelson, 2005; Lee, 2013; Tidd & Bessant, 2013). Considering that the innovation process is implemented primarily by companies, productivity gains and economic growth in countries ultimately depend on innovative companies.

On the other hand, the innovations that companies implement, individually or together with their partners, reflect varied creative activities, such as imitations, trial and error, and experimentation to solve problems in products and processes, various models of design and engineering, and various levels of R&D (Bell, 2009; Bell & Figueiredo, 2012). Therefore, several economically relevant technological innovations implemented by companies do not always derive from science. On the contrary, the opposite is often true. In addition, several technological innovations in the industry have created the basis for an agenda and advances in science. As largely demonstrated in the literature, the idea of technological innovation as a mere application of scientific knowledge is misleading. As Nathan Rosenberg states, such a perspective obscures an elementary point that technology is itself a body of specific knowledge about certain types of events and activities (Fagerberg et al., 2005; Freeman, 1974; Kline & Rosenberg, 1986; Rosenberg, 1982).

It is also worth remembering the classic studies by E. Mansfield, which demonstrated that the vast majority of product and process innovations in different industries in the US were implemented without the benefit of basic research carried out at universities (Mansfield, 1991). For a long time – and even today – relevant technological knowledge has been accumulated based on experimentation and trial and error without a scientific basis. Therefore, to a considerable degree, there are situations in which technological knowledge precedes scientific knowledge. For certain production activities, there is still no deep scientific knowledge. For example, the high costs of aircraft development are associated with long tests – and consequent design changes based on these tests – because there are no consolidated theories about turbulence and compressibility for optimizing aircraft designs. A similar situation currently occurs in the development of algorithms for cybersecurity.

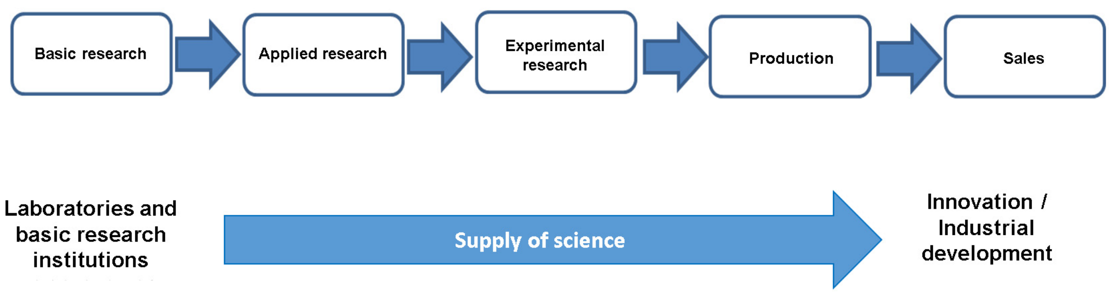
Due to economic incentives, some technological advances based on accumulated technical knowledge occur prior to scientific understanding. Thus, the notion that scientific research would appear first and lead to application in technology is simplistic and naive. Technological knowledge also plays an important role in shaping the scientific agenda.

Subsequent analyses have shown that the way companies seek university scientific knowledge to innovate varies considerably across industrial sectors (Salter & Martin, 2001). The success of the interaction between company and university depends largely on the impetus to innovate and on the ability to absorb knowledge at the company level (Cohen & Levinthal, 1990; Meyer-Krahmer & Schmoch, 1998). On the other hand, such success also depends on the capacity and interest of the university and its researchers to understand the nature of the companies' problems and demands.

However, the company's primary role when implementing innovation is not widely understood, even within the scope of policymakers. Universities and public research institutes are mistakenly assigned the role of main (or even "exclusive") actors in the innovation process, especially in developing economies. The notion that technological innovation, at the industry and company level, still **results linearly** from the application of scientific knowledge developed in universities and research institutes is reiterated. As mentioned earlier, this linear perspective does not reflect the reality of the technological innovation process in the industry and the economy.

In Brazil, the prevailing perspective is that scientific efforts precede industrial innovation. The debate on science, technology, and innovation (ST&I) policy in Brazil is still strongly influenced by a linear perspective on innovation, where the public policy attention must focus on strengthening research capacity in universities and government research institutes. This perspective, which emerged around 1945, was widely questioned and lost its validity as early as the 1970s (Cruz, 2003). Figure 4 represents the essence of this linear perspective.

FIGURE 4 REPRESENTATION OF THE LINEAR MODEL OF INNOVATION

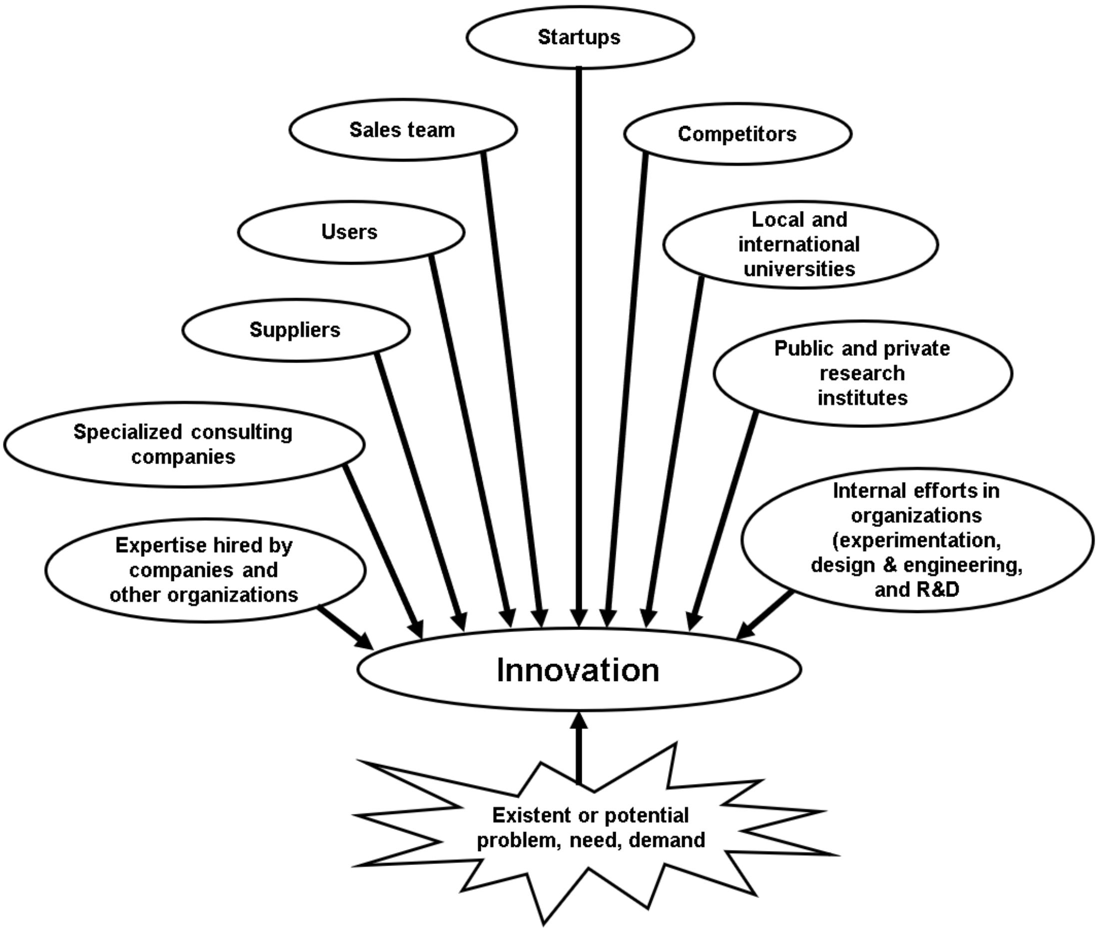


Source: Elaborated by the authors.

This is an emphasis on the supply-side that favors scientific research excellence (especially basic research) and human resources development in science to the detriment of efforts in the field of technological and industrial development. It reflects a mistaken notion that innovation is the "commercialization of science" (Caraça, Lundvall & Mendonça, 2009). However, abundant empirical evidence documented in the literature demonstrates that innovations that substantially impact the economy do not necessarily depend on science. On the contrary, there is a historical recognition of the influences of technological advances in the industry, based on design, engineering, experimentation, and trial and error that determine scientific advances or shape the scientific research agenda (Caraça et al., 2009; Rosenberg, 1982). In Brazil, as observed by Cruz (2003), the mistaken notion that technological innovation occurs more in the university than in the company tends to prevail. This does not mean that we are suggesting an inferior role for science in economics and society. On the contrary, science plays a fundamental role in the socio-economic development of countries, as we will discuss in the following sections.

Although science may be important for the innovation process, it has long ceased to be the priority source for innovation (Caraça et al., 2009). Over the past few decades, numerous studies have demonstrated that the innovation process is increasingly interactive, interdependent, and derived from diverse sources, both internal and external to organizations (Chesbrough, 2003; Lundvall, 1992), as shown in Figure 5. Furthermore, several classic studies demonstrate that the innovation process is triggered by economic incentives, especially potential and existing needs, problems, and demands (Kline & Rosenberg, 1986; Rosenberg, 1992; Tidd & Bessant, 2013).

FIGURE 5 REPRESENTATION OF THE DIFFUSE SOURCES OF INNOVATION



Source: Elaborated by the authors.

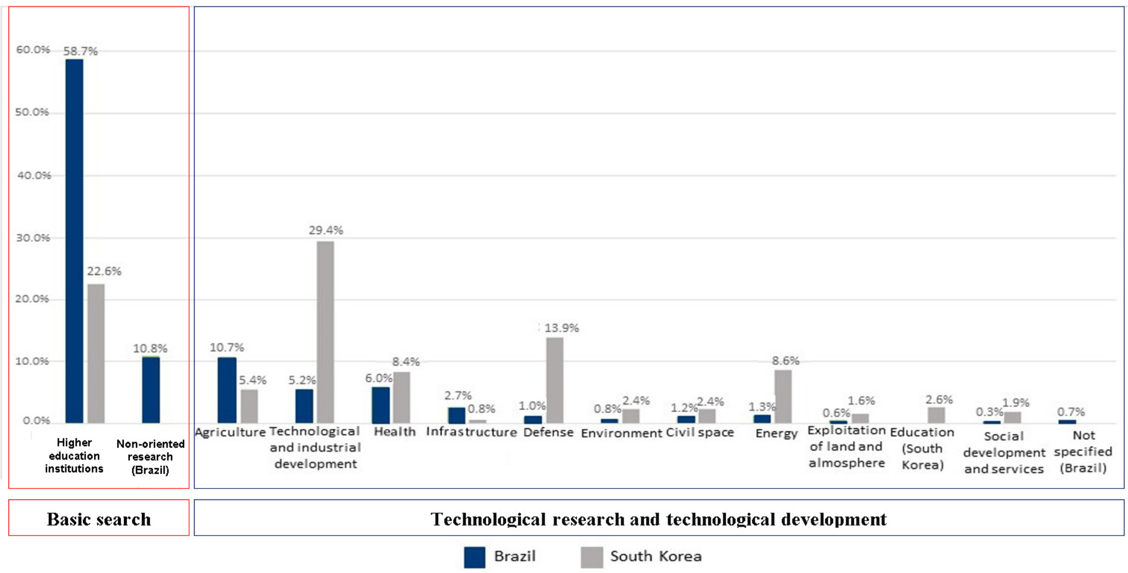
Innovation implies a wide range of activities, as observed in organizations and countries that have obtained innovative and productive performance. These activities range from creative imitation and replication, including processes of experimentation, design, and engineering (D&E), to the different levels of R&D (from trouble shooting and production support to applied and basic science) (Bell & Figueiredo, 2012).

2.3 The distribution of government expenditures on R&D in Brazil, by socioeconomic objectives

As already mentioned, R&D investments are not exclusively aimed at generating technological innovation. Other goals stand out, such as contributing to a scientific base in the country or improving economic activity regulation. As our focus here is on innovation and productivity, the national expenditure on R&D can be considered ineffective regarding the creation of innovation to be implemented in the economy. Therefore, one issue related to the private sector's little participation in R&D investments is the distribution between basic science and technological development. To elaborate, we present a brief comparison between Brazil and South Korea.

In the late 1960s, Brazil and South Korea performed similarly in terms of technological and economic development indicators. Over forty years later, South Korea has become a high-income economy, with a high level of productivity and with global technological and commercial leadership in various industries. Brazil, in turn, remains stagnant in the condition of income and medium technology, with a low productivity rate, slow economic growth, and consequent social effects. Figure 6 presents an approximate comparison between Brazil (federal and state levels) and South Korea regarding the distribution of government spending on R&D, per socio-economic objectives, for the period 2000-2015.

FIGURE 6 **BRAZIL *VS.* SOUTH KOREA: DISTRIBUTION OF GOVERNMENTAL EXPENDITURES IN R&D, PER SOCIO-ECONOMIC OBJECTIVES (2000-2015)**



Notes:

(1) Brazil: average of the period 2000-2014; South Korea: average of the period 2000-2015.

(2) As for the socio-economic objective "higher education institutions" (HEI), according to the MCTIC (our translation): "Some expenses are subtracted from the annual budget executed by federal and state institutions offering Master and PhD degrees recognized by the Brazilian agency CAPES in order to estimate the portion of resources directed to graduate programs. These expenses are interest and debt amortization, expenses related to judicial sentences, expenses with inactive personnel and pensioners, and university hospitals' maintenance. The result obtained after the subtraction is multiplied by the quotient [number of professors in graduate programs/number of professors of the HEIs in the respective year] (except for the years 2004 to 2006 in federal institutions. For those years, the calculation considered the quotient based on numbers from 2003)." According to the MCTIC, this category includes investments in buildings and facilities, as well as salaries for professors and other professionals.

(3) According to OECD accounting (see MCTIC), in OECD countries, the category "non-oriented research" is included in "higher education institutions."

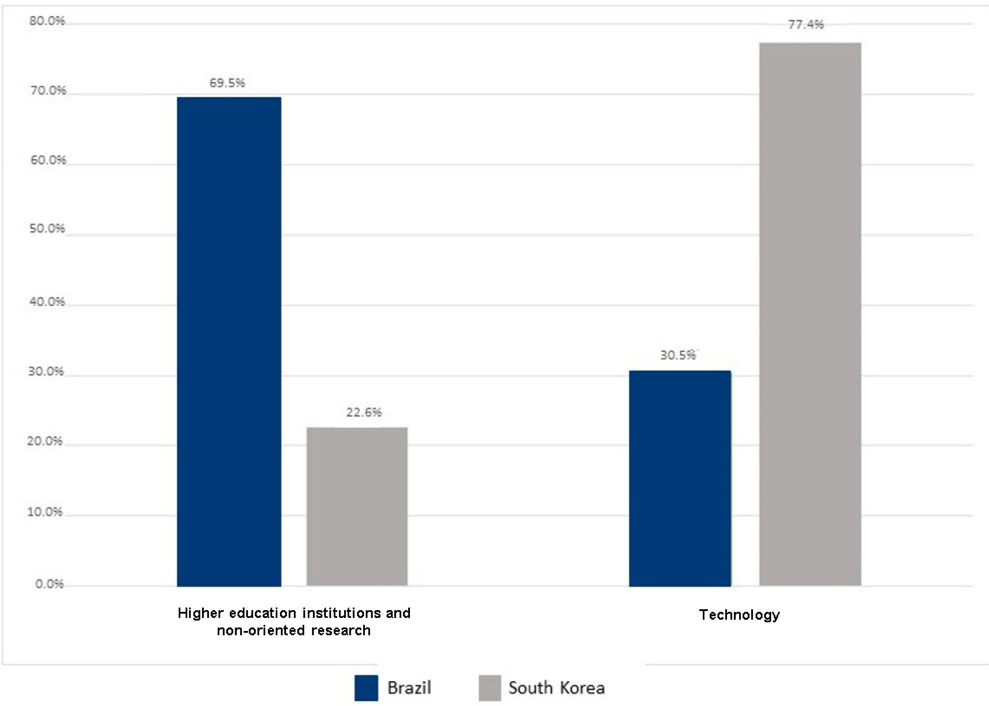
(4) Percentages calculated based on values in USD constant in 2011.

Source: Elaborated by the authors based on data from MCTIC (Brazil) and OECD (https://stats.oecd.org), chapter GBARD.

In Brazil, universities (most of them are public institutions) have absorbed most of the government's investment in R&D (UNESCO Science Report 2017 - www.en.unesco.org/unesco_science_report). At the state level in Brazil, universities accounted for the vast majority of R&D investments, from 62.2% (2000) to 71.4% (2014), followed by "non-oriented research" (average of 14%, 2000-2014). This means a large part of the expenditures are concentrated in higher education and scientific production, to the detriment of technological development and implementation of innovations in other components of the innovation system, especially companies.

In South Korea, from 2000 to 2015, government spending on R&D with universities grew from 19.8% to 20.8%. The expenditures on "technological and industrial development" are noteworthy: from 24.2% (2000) to 29.2% (2016). Figure 7, on the other hand, presents the same information but in an even more compact way. Government expenditures on technology R&D refer to the socio-economic objectives of Figure 6, excluding expenditures with "higher education institutions" and "non-oriented research."

FIGURE 7 BRAZIL AND SOUTH KOREA IN INVERSE POSITIONS



Note: The same notes for Figure 6 apply.
Source: Elaborated by the authors based on data from MCTIC (Brazil) and OECD (https://stats.oecd.org), chapter GBARD.

Much of South Korea's R&D spending has been directed towards technological development and innovation. These data corroborate the existing studies on how South Korea has managed to evolve from being an agrarian country, with low rates of productivity and income, and low industrial and technological development (1950s and 1960s), to a high-income economy with technological and commercial leadership in several types of industry: the country strongly emphasized the participation of companies in R&D investment. At the same time, government R&D investments focused on applied research and experimental development. These types of R&D expenditure support the accumulation of technological capacities for innovation at the company level (Kim, 1997; Lee, 2013).

After achieving a high level of income and a high level of industrial and technological development, South Korea accelerated its government efforts towards basic research while paying attention to applied research and experimental development (see OECD www.stats.oecd.org). With the strengthening of its scientific base, associated with a strong technological base in the industry, South Korea can proactively take advantage of the new windows of opportunity, especially in new technologies. There is currently a more interactive and ambidextrous relationship concerning investments in science and technology. South Korea's experience sends an important message about the effectiveness of R&D expenditures for other emerging economies, such as Brazil. The evidence from South Korea and other countries that have evolved from a similar situation contradicts the prevailing logic in Brazil, which privileges the focus of investment efforts on science.

At this point, it is important to comment on this centralization of R&D activities in universities and other public research institutions (Bell & Figueiredo, 2012; Bell & Pavitt, 1993). First, it is a phenomenon prevalent in developing economies. It reflects a specific notion of the technological innovation process and a deficiency in the organizational and management basis for R&D efforts. More specifically, it usually implies an exaggerated emphasis on the supply side of R&D (Bell, 2009). It considers universities and public research institutions as the locus of innovation and primary generators of resources for technological innovation in the industry. This is the case, for example, with the regulatory and legislative framework of the oil and gas industry in Brazil (Ghiorzi, 2019). This perspective tends to generate an exacerbated expectation about the results that universities can deliver, generating a negative assessment of their performance (Caraça et al., 2009).

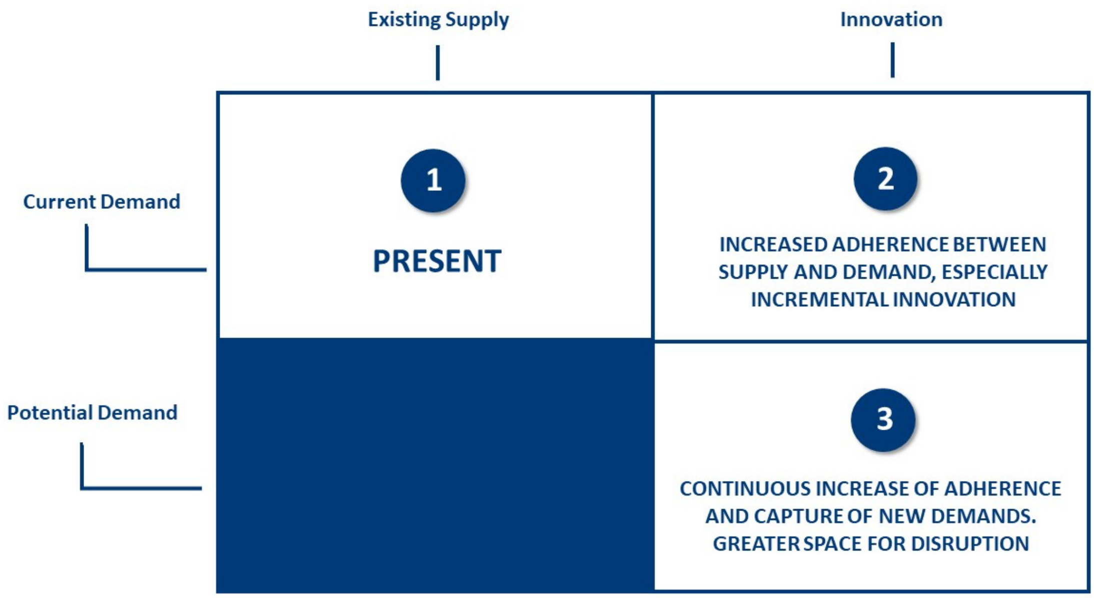
Second, it expresses a notion of the sectoral innovation system that tends to ignore users and the other different actors involved in producing goods and services. These actors link the **demand** for technological innovation resources and play a key role in their implementation (Bell, 2009). This deficient organizational base and other factors – such as the precarious management of universities and public research institutions (although there are exceptions) and budget irregularities and instabilities – not only limit the pressures of demand for R&D but compromise the effectiveness of national research and development.

It is worth emphasizing that we are not advocating the lesser importance of basic science or research. On the contrary, we share the perspectives and evidence on the various benefits of science and basic research for the economy and society, which includes (Martin & Tang, 2007; Pavitt, 1991; Soete, Verspagen & ter Weel, 2010): the increase in useful knowledge; training of qualified professionals; creation of new scientific instruments and methodologies; formation of networks and enhancement of scientific and social interaction; increasing capacity to identify and solve technologic problems; creation of new companies; generation and provision of social knowledge; and overcoming situations of imprisonment in existing solutions. We also understand that public R&D investments do not involve crowding out nor replacing private investments. They complement private investments to meet existing and potential demands, problems, and needs of the economy and society (Georghiou, 2015).

3. INNOVATION SUPPLY AND DEMAND

There are different concepts linked to innovation, such as incremental and disruptive innovation, innovation portfolio and risk management versus innovation return, innovation constraints and limitations. All can be framed or analyzed using a simple design that relates the supply of innovation to its demands (Figure 8).

FIGURE 8 RELATION BETWEEN INNOVATION SUPPLY AND DEMAND



Source: Elaborated by the authors.

Quadrant number **1** is the status quo, where the existing supply matches the current demands and, usually, can be adapted to the demands' minor variations. Number **2** shows the innovations that are, above all, incremental and generally focus on efficiency gains, either through process improvement or through slight product improvements. The low cost, especially for dissemination, allows meeting the demands that have not yet been met. Quadrant number **3** emphasizes the ability to meet new demands with less attention to cost reductions. The difference between increment and disruption lies in the size of the leap that is made and the speed at which it is achieved. The shaded quadrant corresponds to potentially existing demands that are currently not satisfied.

The natural path in an economy is to work on adding quadrant **2** to **1**, then **3** to **1** and **2**, successively. Therefore, the use and diffusion of innovations constantly increase, adding value to the economy. From the point of view of economic sustainability, it is difficult to operate quadrant **3** directly. The reason is that disruptive innovation processes (in the radical sense) have many risks: (a) by definition, the volume of investments needed to reach a result is more volatile with an upward bias; (b) the return is also volatile, usually, with a downwards bias.

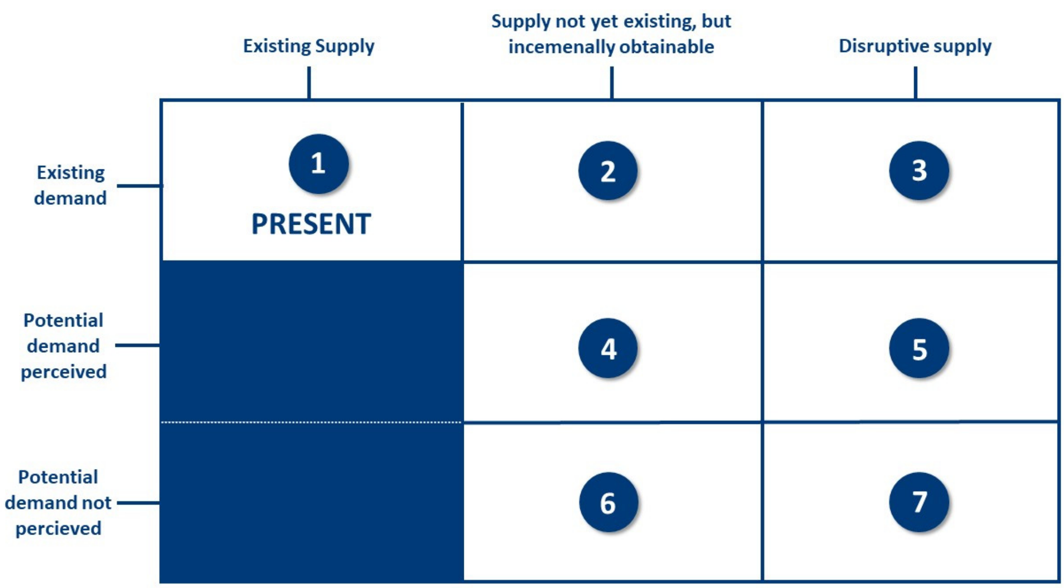
Brazil distributes its R&D investments inefficiently and adopts few, if any, of the security measures and procedures necessary to manage the risk of the innovation portfolio. In general, the country does not know how to do this. First, the distribution between basic science and technology is more in search of something in quadrant **3** than in quadrant **2**.

Second, the distribution of government investment in R&D in Brazil, as shown above, is concentrated in basic science. Thus, public expenditure is primarily oriented towards promoting science itself. Within this sphere, it is extremely dispersed in numerous research lines due to the notion of adopting minimum investment sizes, limiting its effectiveness. Also, the investments are subject to the uncertainties of government budget execution.

Third, the low, almost nil, proportion of defense investment (Figure 6) means that a potent and focused subsidy instrument, where results are sure to happen, is not exploited. Defense investment, together with others, reduces the return volatility. At the same time, it can be used as an intelligent source of subsidies for technological development, the demand for qualified professionals, and innovation, including the innovative activities of startups and specialized SMEs.

When resuming and deepening the previous analysis, the potential demands can be divided between those we perceive today and those we do not know yet. On the other hand, something similar can be done with innovations. This would give us a refinement, as shown in Figure 9. The problem becomes clear here: what is the correct sequence of rectangles to be occupied? It does not seem that Brazil has understood this issue correctly.

FIGURE 9 A MORE SOPHISTICATED PERSPECTIVE OF THE RELATION BETWEEN INNOVATION SUPPLY AND DEMAND



Source: Elaborated by the authors.

4. POLICY DESIGN FOR TECHNOLOGY INNOVATION

As observed in the previous section, national innovation strategies are necessary due to a growing need for countries to gain productivity and compete globally with added-value and innovative products. Simultaneously, **market forces alone do not guarantee the implementation of innovations at the company level**. The following points must be considered:

(1) It is important to emphasize that innovation **does not** mean only new ideas, creativity, and inventiveness, which is a notion that has always supported scientific policies in the past. Innovation involves adding value to ideas and implementing them. **It aims to increase productivity and respond to society's existing and potential problems, demands, needs, and challenges.** Because it is solution-oriented, innovation is a relevant element in the public managers' work when facing technical, economic, and social issues. As observed by Joseph Schumpeter (Schumpeter, 1934) and confirmed in subsequent studies (Fagerberg et al., 2005), innovation primarily involves the recombination of existing technologies.

(2) Innovations reflect and derive from a broad spectrum of activities and technological capabilities that involve experimentation, creative imitations, problem-solving based on engineering, design, and development, up to the most advanced level of R&D within companies and their network of partners. Therefore, a more **comprehensive** and **inclusive** perspective on the innovation process is needed.

(3) Therefore, it is a mistake to associate innovation with the mere application of scientific knowledge. However, as mentioned earlier, this linear perspective on innovation – i.e., basic scientific research carried out in universities, and public research institutions would lead to technological innovation – is still invoked to justify the increase in government R&D expenditures. As stated, several relevant innovations do **not necessarily** depend on science.

(4) The innovation process has become increasingly fragmented and internationally and organizationally dispersed. Innovative companies collaborate with several partners, suppliers, users, startups (with different purposes), specialized consultants, competitors, universities, research institutes. However, this collaboration does not mean transferring innovation activity to partners. The producing company continues to retain the fundamental role of leading the innovation process.

(5) Innovation policies involve public intervention to support the generation and diffusion of new products, processes, or services. They also support new business models and organizational arrangements, new forms of product commercialization and distribution, new resources for production, and other innovative activities.

Thus, this study focuses on **increasing private sector investment in R&D and the rate of innovation** in the economy. The literature and countries' experiences identify policy instruments aimed at directly and/or indirectly stimulating innovation. Such instruments can be classified as related to the **supply side** (those that influence the generation of innovation) or to the **demand side** (i.e., influencing those who require/desire, buy, or apply innovations and the resources needed to implement such innovations).

Policies focused only on the supply side tend not to consider commercial applications and have been insufficient for innovation generation and implementation. At the same time, there is a consensus on the fundamental role of **companies** and their partners in the process of innovation and increased productivity. Over the past few decades, several developed countries have valued **demand-driven** innovation policies connected with supply policies.

Such policies can and should be designed considering the use of the instruments presented in Box 1. They are classified according to their main focus on supply or demand. The examples in Box 1 are not exhaustive but offer an idea of the complexity of the analysis to be made. Figure 10 shows some examples of interactions between the supply and demand dimensions of innovation-oriented public policies.

BOX 1 EXAMPLES OF THE INNOVATION POLICY'S SUPPLY AND DEMAND INSTRUMENTS

Examples of the innovation policy's supply and demand instruments	Supply	Demand	Goals and expected impacts
Fiscal incentives to R&D	✓		Increase R&D spending
Direct support for R&D in companies	✓		
Access to financing and loan guarantees	✓		
Policies for training and qualification of human resources by companies	✓		Increase personnel's qualification (skills)
Policies for migration of human resources and protection of employment	✓		
Measures to support the protection of intellectual property	✓		Obtain access to specialists
Policy to support entrepreneurship (including incubators and similar mechanisms)	✓		
Technical support and advisory services	✓		
Cluster policy	✓		Development of systemic capabilities
Policy to support collaboration in R&D	✓		
Policy to form innovation networks	✓		
Stimulate demand for innovation		✓	Enhance demand for innovation from the private sector and consumers
Public procurement policies		✓	
Policies for pre-commercial procurement		✓	
Policies for cooperative purchases and catalysts (government in connection with companies)		✓	
Creation of innovation guidelines and tools to support the processes of government procurement with examples of best practices		✓	
Measures to reduce the barriers to SME's participation in public procurement		✓	

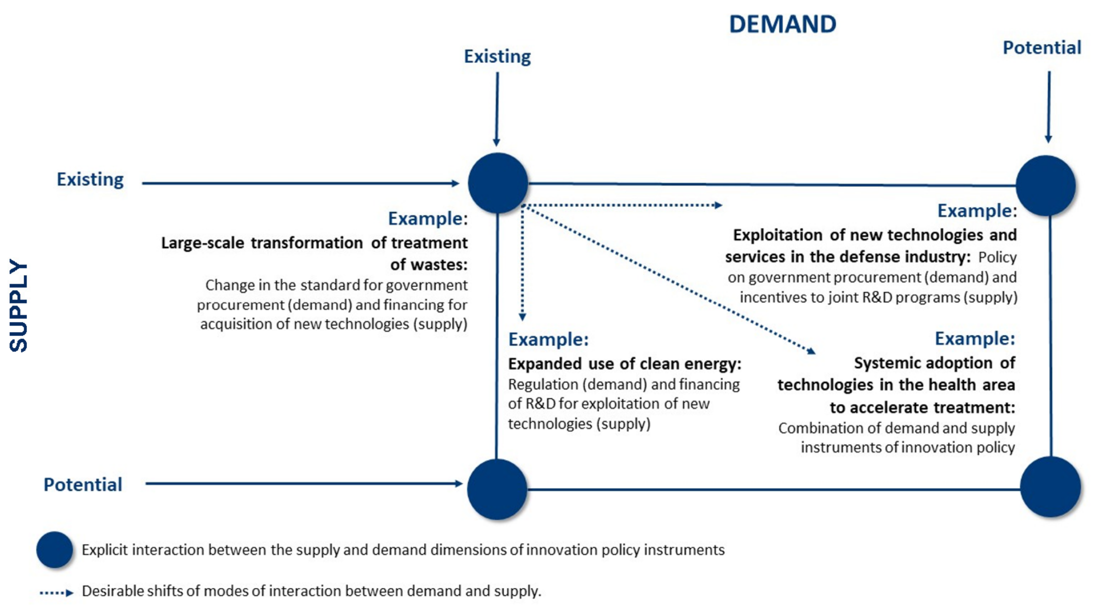
Continue

Examples of the innovation policy's supply and demand instruments	Supply	Demand	Goals and expected impacts
Competitive processes for innovative entrepreneurs in government procurement		✓	
Contracts for reimbursement of costs		✓	
Creation of incentives to stimulate demand for new products and services		✓	
Measures to increase awareness and stimulate consumers to buy new products and services		✓	
Various standardization measures		✓	
Various forms of regulation		✓	
Innovation inducement prizes		✓	
Measures to stimulate the development of technological capabilities for innovation by companies	✓	✓	Development of capabilities for innovation in firms along the value chain
Spillovers generated by technological innovations in the defense industry	✓	✓	
Organizations dedicated to the alignment between supply and demand of universities, public research institutions, and firms	✓	✓	

= Intersection between supply and demand.

Source: Adapted from Edler (2013), Edler and Fagerberg (2017), and European Commission (2015).

FIGURE 10 EXAMPLES OF THE INTERACTION BETWEEN THE INNOVATION POLICY DIMENSIONS OF SUPPLY AND DEMAND



Source: Elaborated by the authors.

Over the past 20 years, Brazil has created a set of policies to support innovation. These policies have been implemented in the form of several programs and actions. **It is interesting to note that Brazil's policies over the past 20 years have mostly emphasized the supply side to the detriment of the demand side.**

Brazil is among the five countries with the **greatest fiscal generosity in fiscal incentives for innovation in companies** (deductions, tax credit, accelerated depreciation) (Araujo, 2012). However, the result in terms of innovation and productivity has been insignificant. For Carlos Américo Pacheco, "the Brazilian incentive system as a whole has, to date, been ineffective in changing the Brazilian innovation framework" (Pacheco, 2011, p. 272). In addition, it is important to note that programs and actions lack **more systematic assessments of their performance and impacts**. Some programs and actions are discontinued without at least undergoing a process to evaluate the benefits generated. On the other hand, innovation incentive policies in Brazil tend to emphasize procedural aspects, such as an exacerbated focus on bureaucratic and punitive issues, to the detriment of measuring impacts and results regarding the implementation of innovations with an increasing degree of novelty and complexity and the strengthening of the international competitiveness of the industries targeted by these policies.

5. TECHNOLOGICAL INNOVATION: THE NEED FOR AN ORGANIZATIONAL BASE

The widespread idea is that technological innovation requires a stock of creative and qualified professionals and advanced facilities (machines, equipment, laboratories, and intelligent buildings). However, this is a limited concept. Creative and qualified human capital is obviously necessary to implement innovation, but it is not enough. Innovation is not merely creativity or brilliant ideas. It involves a **process of transforming** an idea into practical and commercial application, in the form of a product or service that adds value, meets a demand (existing or potential), and complies with technical, economic, and commercial feasibility requirements. For this transformation process to occur, an organizational base and good management are necessary (Figueiredo, 2015).

At the company level, where technological innovation primarily occurs, this organizational and managerial basis involves a set of organizational routines, procedures, and structures dedicated to innovation, such as product and process design and development units, engineering, R&D, and the company's network of partners. Non-technological areas are also involved, such as marketing, finance, operations, distribution, and the interface with the organization's external collaboration network.

In other words, the implementation of innovations depends on the combination of human capital, structure (equipment, machines, database, laboratories), and organizational and managerial capital. The latter also integrates and coordinates the previous components in achieving innovations. The symbiotic relationship between these components forms a strategic asset called **technological capability** (Figueiredo, 2001, 2015).

However, it is important to mention a subtle distinction between ***two types of technological capabilities*** (Bell & Figueiredo, 2012; Bell & Pavitt, 1993). The first refers to **production or operational technological capability**, which is the ability to ***use*** or ***operate*** existing technologies and production systems. The second concerns the capabilities to implement changes in existing technologies and production systems and/or create and develop new technologies. They are called **technological innovation capabilities**.

These two capabilities can be developed simultaneously by companies and countries. However, some of them may become trapped at the level of production or operational capabilities. In these cases, they become *mere users or operators*, albeit efficient, of technologies and production systems from other companies and countries (Bell & Figueiredo, 2012; Figueiredo, 2015). *Making the transition from the accumulation of technological production or operational capabilities to technological innovation capacities involves, to a great extent,* ***strategic options*** *for companies and countries* (Figueiredo & Cohen, 2019). Several companies and countries have managed to make this transition effectively. In Brazil, there are some inspiring examples, as mentioned in Section 1.

The companies have played the leading role in the development of these technological innovation capabilities. However, this task has been increasingly shared with and supported by suppliers, key users, universities, and research institutions (Figueiredo & Cohen, 2019; Figueiredo, Larsen & Hansen, 2020). Therefore, and more specifically, for companies to innovate, be competitive, and generate a significant contribution to the country's growth, they must accumulate technological innovation capabilities. Thus, coordinated actions would be necessary to value innovative activities in companies in terms of design and engineering and help them develop more advanced R&D technological capabilities. This means that policies must be designed as a long-term commitment of the state, regardless of government transitions.

More specifically, contemporary history has demonstrated that an effective transition from the accumulation of *production or operational capabilities* to *technological innovation capabilities* depends, increasingly, on competent government policies. Specifically, this effective transition has been characterized by government interventions, the main component of which involves developing innovative technological capabilities *at the company level* and not just at the level of public universities and institutions.

6. WHAT WE SAID, WHAT WE DIDN'T SAY, AND MORE

Topics related to science, technology, and innovation (ST&I) policy formally entered the agenda for governmental discussion and action in Brazil in the late 1960s after the elaboration of the I National Development Plan (PND, 1972/74) and the Basic Plan of Scientific and Technological Development (PBDCT, 1973/74) followed by II and III PBDCTs. During the late 1990s, the federal government, through the Ministry of Science and Technology, led an initiative to systematize, in a detailed and exhaustive manner, the various elements related to the ST&I system considered necessary for national development, by issuing the document *Ciência, tecnologia e inovação: desafio para a sociedade brasileira – Livro verde* (science, technology, and innovation: challenge for Brazilian society – Green Book) (Ministério da Ciência e Tecnologia [MCT], 2001).

In September 2001, as a result of the national ST&I conference, the *Livro branco da ciência, tecnologia e inovação* (white paper on science, technology, and innovation) was created. Its goal was "to point out ways for Science, Technology, and Innovation to contribute to the construction of a more dynamic, competitive, and socially fairer country" (MCT, 2002, p. 21) for the period 2002-2012. Thus, some of the topics connecting ST&I and national development have been recurrent in the Brazilian debate since the 1960s (Figueiredo, 2004).

From the beginning of the 2010s, efforts were made around the National Strategy for Science, Technology, and Innovation (ENCT) – versions 2012-2016, 2015-2020, 2016-2022. This action was welcome due to the nature of its various intentions. However, despite all efforts made over the past 50 years, little advances can be observed in the field of productivity and technological and industrial development, as the indicators explored before demonstrate. On the contrary, over the past few decades, except for some areas, Brazil has experienced a worrying systematic departure from the international frontier of technological innovation. At the same time, Brazil has lost relevant windows of opportunity in terms of technology and demand.

There seems to be a substantial mismatch between *intentions* and *achievements*, difficulties in taking advantage of windows of opportunity, and difficulties in solving issues already overcome in other countries. It is possible to infer a severe problem of an organizational and institutional nature behind this mismatch (Figueiredo, 2004). Currently, discussions are focused on the National Innovation Policy (PNI), which represents a new opportunity to identify key issues deserving attention and develop implementation strategies that can lead Brazil out of technological backwardness and a definite increase in the country's innovation rate. It is an opportunity to move from broad and diffuse proposals to lines of action focused on truly relevant issues that change the status quo.

The issue of technological innovation tends to become central to the discussion about the future of Brazil. Correcting the current process, which has several significant results but with a low return, is a complex task, as it will affect consolidated power structures around the distribution of public funds. Preferably, the state has to invest more, but there is no excuse for not increasing the social return on investments, regardless of whether this increase occurs.

In the short term, there is no fiscal flexibility for the state to increase its spending on R&D. Also, in the short term, **R&D risk-taking by the private sector is small**. Although the context is challenging, some actions can be taken. It is necessary to look at the details of the R&D investment process and see how it can be optimized. Incentive schemes need to be studied, and **the link between investment in basic science and technological development needs to be further explored and better understood.**

It is crucial to revise the investments, identifying the elements that are more or less important, improving the rank of priorities. Also, policymakers have to pursue a common understanding of the roles of the actors involved in the innovation process at the national level.

Again, we recognize that R&D investments do not have the exclusive purpose of generating technological innovation. **There are important objectives, such as contributing to a scientific base in the country or improving the economic activities' regulation**. At the same time, it is necessary to consider the urgency of increasing the rate of innovation and productivity in the Brazilian economy. In this sense, the concern with increasing the efficiency of national spending on R&D in Brazil is legitimate.

The agents responsible for combining supply and demands for innovation and the potential demands in the decision-making process regarding investment in technological innovation are essential. A country's socio-economic development depends, to a large extent, on a strong scientific base, reflected in universities capable of forming a critical mass and carrying out research in the various areas of knowledge. As the renowned professor José Goldemberg (2015, p. 53, our translation) points out, the search for excellence in universities contributes to "giving society the scientific, technical, and artistic knowledge indispensable for its development."

Industrially and economically advanced countries have created a vast technological domain shaped by economic demands, needs, and incentives. The construction of this technological domain was linked in several ways to science. However, considering that scientific research is a costly activity, it is expected to generate economic returns and well-being to society (Rosenberg, 1982, and related studies).

In contexts where research programs have contributed effectively to technological and economic development, they have not operated as "ivory towers." On the contrary, they were oriented towards pressing needs and problems in industry and society (Mazzoleni & Nelson, 2007), and similar cases are observed in Brazil. For this reason and based on successful experiences, it would be beneficial for national development to devote attention to technological development and innovation, as well as to how science could contribute effectively. Scientific development plays a highly relevant role in a country's technological and socio-economic development, which means that science must have a purpose.

Additionally, it is necessary to reiterate that innovation should not be associated with isolated events and should make a change. **Innovation is a *process***, and it is hard. Far from reflecting any kind of automaticity, innovation involves investments and deliberate efforts to build its main resource: *technological capabilities*. The innovation process and its impacts on increasing productivity and adding value to the economy are, to a great extent, a reflection of how companies (and their network of partners) and countries accumulate technological capacities (Bell & Figueiredo, 2012). Companies in developing economies, such as Brazil, have deficiencies in technological innovation capabilities for historical reasons. Thus, the process of accumulating technological capabilities for innovation, at the level of companies and industries, should be at the center of the debate and actions of innovation policies in Brazil.

Finally, we emphasize that increasing the innovation rate is one of the main conditions for Brazil to accelerate its economic growth and social development. The innovation process requires investments and deliberate efforts. However, the government's capacity for new expenditures in this area is increasingly limited. Simultaneously, Brazil's investment in R&D over the past 15 years is far from insufficient. There is a widespread insistence for Brazil to increase its R&D investment to approach the average OECD countries of 2.4% of GDP. However, it would be wiser to prioritize increasing the effectiveness of existing expenditures before simply claiming to increase them. Intensifying the existing pattern of R&D expenditures would continue to generate insufficient results.

However, if Brazil's current investment pattern in R&D remains as it is, we will most likely remain stationary in the condition of an economy of middle-income technology: high production costs, low capacity for technological innovation, and slow economic growth. The social consequences of this condition are known. Therefore, we need to move forward in the debate on increasing the **efficiency** of expenditures on R&D in Brazil; after all, effective R&D investment is a duty for the present generation and a social right for future generations.

7. SUGGESTIONS FOR FUTURE RESEARCH

The discussion put forward in this article paves the way for applied research projects related to technological innovation and its implications for economic development in Brazil. Box 2 below presents a non-exhaustive list of some topics to be addressed in future research.

BOX 2 TOPICS ON TECHNOLOGICAL INNOVATION IN BRAZIL TO BE ADDRESSED IN FUTURE APPLIED RESEARCH PROJECTS

Topics of a microeconomic nature	Topics of a macroeconomic nature	Topics linked to innovation policy	Topics linked to innovation management at the firm level and innovation systems	Opportunities for innovation
The effect of the internal debt's composition on the likelihood to invest in R&D The effect of oligopolization on R&D investments at the firm level The microeconomic aspects of current policies on R&D subsidies	The cost of macroeconomic policies on subsidies to innovation Examining the exchange rate strategy together with the faster innovation rate and greater penetration in international markets "The Europe effect" on investments in innovation The growth of the service sector, the nature of its innovation process, and the impact on productivity	In-depth analysis of the profile of R&D investments in different countries to explain successful measures The current investment in Brazil from the standpoint of the BSC of the country and its companies The hindrances of the current rules and regulations on R&D Fiscal policy regarding R&D Proposals to revise R&D incentive policies Ranking of the instruments of innovation policy according to their efficacy Identify ways to systematize the assessment of programs and actions defined in governmental innovation policies	Paths to match demand and supply in the design and implementation of innovation policies How human resources management affect the innovation process Examining processes to ensure the supply 'niche' meets demand in innovation projects Paths of accumulation of innovative technological capabilities in firms and their impacts on productivity Identify together with universities and research institutes the organizational and legal barriers that inhibit the interaction between them and companies	Process of R&D investments spillovers in large companies Developing CRM/ Marketplace for innovation to stimulate the interaction between companies and universities, and companies and research institutes Identify opportunities for industrial diversification and the creation of new industrial sectors and companies The process of adding value to the industry through service activities
↓ 3 Topics	↓ 4 Topics	↓ 7 Topics ↓ 23 TOPICS	↓ 5 Topics	↓ 4 Topics

Source: Elaborated by the authors.

REFERENCES

Araujo, B. C. (2012). *Políticas de apoio à inovação no Brasil: uma análise de sua evolução recente* (Texto para Discussão 1759). Rio de Janeiro, RJ: Ipea.

Audretsch, D., Coad, A., & Segarra, A. (2014). Firm growth and innovation. *Small Business Economics*, *43*(4), 743-749.

Bell, M. (2009). *Innovation capabilities and directions of development* (STEPS Working Paper, 33). Swindon, UK: Economic and Social Research Council.

Bell, M., & Figueiredo, P. N. (2012). Building innovative capabilities in latecomer emerging market firms: some key issues. In J. Cantwell, & E. Amann (Eds.), *Innovative firms in emerging market countries* (pp. 24-109). Oxford, UK: Oxford University Press.

Bell, M., & Pavitt, K. (1993). Technological accumulation and industrial growth: contrasts between developed and developing countries. *Industrial and Corporate Change*, *2*(2), 157-210.

Caraça, J., Lundvall, B-Å., & Mendonça, S. (2009). The changing role of science in the innovation process: from queen to cinderella? *Technological Forecasting and Social Change*, *76*(6), 861-867.

Cassiman, B., Golovko, E., & Martínez-Ros, E. (2010). Innovation, exports and productivity. *International Journal of Industrial Organization*, *28*(4), 372-376.

Chesbrough, H. W. (2003). *Open innovation: the new imperative for creating and profiting from technology.* Boston, MA: Harvard Business School Press.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, *35*(1), 128-152.

Confederação Nacional da Indústria. (2018). *Competitividade Brasil 2017-2018: comparação com países selecionados.* Brasília, DF: CNI.

Cruz, C. H. B. (2003). A pesquisa que o país precisa. *RAE Executivo*, *2*(1), 17-28.

Dohnert, S., Crespi, S., & Maffioli, A. (2017). *Exploring firm-level innovation and productivity in developing countries: the perspective of Caribbean small states*. Washington, DC: Inter-American Development Bank.

Edler, J. (2013, November). *Review of Policy Measures to Stimulate Private Demand for Innovation: concepts and effects* (Working Paper n. 13/13). Manchester, UK: Manchester Institute of Innovation Research, University of Manchester. Retrieved from https://media.nesta.org.uk/documents/review_of_policy_measures_to_stimulate_private_demand_for_innovation._concepts_and_effects.pdf

Edler, J., & Fagerberg, J. (2017). Innovation policy: what, why, and how. *Oxford Review of Economic Policy*, *33*(1), 2-23.

European Commission. (2015). *Supply and demand side innovation policies*: *final report.* Luxembourg, Luxembourg: Publications Office of the European Union.

Fagerberg, J., Mowery, D. C., & Nelson, R. R. (2005). *The Oxford handbook of innovation.* New York, NY: Oxford University Press.

Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the penn world table. *American Economic Review*, *105*(10), 3150-3182.

Figueiredo, P. N. (2001). *Technological learning and competitive performance*. Cheltenham, UK: Edward Elgar.

Figueiredo, P. N. (2004). Aprendizagem tecnológica e inovação industrial em economias emergentes: uma breve contribuição para o desenho e implementação de estudos empíricos e estratégias no Brasil. *Revista Brasileira de Inovação*, *3*(2), 323-361.

Figueiredo, P. N. (2015). *Gestão da inovação: conceitos, métricas e experiências de empresas no Brasil* (2a ed.). Rio de Janeiro, RJ: LTC.

Figueiredo, P. N., & Cohen, M. (2019). Explaining early entry into path-creation technological catch-up in the forestry and pulp industry: Evidence from Brazil. *Research Policy*, *48*(7), 1694-1713.

Figueiredo, P.N., Larsen, H., & Hansen, U.E. (2020). The role of interactive learning in innovation capability building in multinational subsidiaries: A micro-level study of biotechnology in Brazil. *Research Policy*, *49*(6), 103995.

Freeman, C. (1974). *The economics of industrial innovation*. Harmondsworth, UK: Penguin Books.

Georghiou, L. (2015, June). *Value of research. Policy Paper by the Research, Innovation, and Science Policy*

Experts (RISE Paper). Luxembourg, Luxembourg: Publications Office of the European Union.

Ghiorzi, T. (2019). É preciso (des)inverter a relação entre inovação e ciência. *TN Petróleo*, *21*(126), 38.

Goldemberg, J. (2015). Em busca da excelência. *Revista USP*, *105*, 51-64.

Hall, B. H. (2011). Innovation and productivity. *Nordic Economic Policy Review*, *2*, 167-204.

Kim, L. (1997). *Imitation to innovation: the dynamics of Korea's technological learning*. Boston, MA: Harvard Business School Press.

Kline, S. J., & Rosenberg, N. (1986). An overview of innovation. In R. Landau, & N. Rosenberg (Ed.). *The positive sum strategy: harnessing technology for economic growth* (pp. 275-304). Washington, DC: National Academy Press.

Lee, K. (2013). *Schumpeterian analysis of economic catch-up: knowledge, path-creation, and the middle-income trap*. Cambridge, UK: Cambridge University Press.

Lundvall, B. A. (1992). *National systems of innovation: towards a theory of innovation and interactive earning.* London, UK: Pinter Publishers.

Malerba, F., & Lee, K. (2020, August). An evolutionary perspective on economic catch-up by latecomers. *Industrial and Corporate Change*.

Mansfield, E. (1991). Academic research and industrial innovation. *Research Policy*, *20*(1), 1-12.

Martin, B., & Tang, P. (2007). *The benefits from publicly funded research* (SEWPS SPRU Electronic Working Paper Series). Brighton, UK: University of Sussex.

Mazzoleni, R., & Nelson, R. R. (2007). Public research institutions and economic catch-up. *Research Policy*, *36*(10), 1512-1528.

Meyer-Krahmer, F., & Schmoch, U. (1998). Science-based technologies: university interactions in four fields. *Research Policy*, *27*(8), 835-851.

Ministério da Ciência e Tecnologia. (2001). *Ciência, tecnologia e inovação: desafio para a sociedade brasileira – livro verde.* Brasília, DF: Author.

Ministério da Ciência e Tecnologia. (2002). *Livro branco: ciência, tecnologia e inovação.* Brasília, DF: Author.

Pacheco, C. A. (2011). O financiamento do gasto em P&D do setor privado no Brasil e o perfil dos incentivos governamentais em P&D. *Revista USP*, *89*, 256-276.

Pavitt, K. (1991). What makes basic research economically useful? *Research Policy*, *20*(2), 109-119.

R&D Magazine. (2019). *2019 global R&D funding forecast*. Retrieved from https://www.rdworldonline.com/2019-rd-global-funding-forecast/

Rosenberg, N. (1982). *Inside the black box: technology and economics*. Cambridge, UK: Cambridge University Press.

Rosenberg, N., Landau, R., & Mowery, D. C. (1992). *Technology and the wealth of nations*. Stanford, CA: Stanford University Press.

Salter, A. J., & Martin, B. (2001). The economic benefits of publicly funded basic research: a critical review. *Research Policy*, *30*(3), 509-532.

Schumpeter, J. (1934). *The theory of economic development*. Cambridge. MA: Harvard University Press.

Soete, L., Verspagen, B., & ter Weel, B. (2010). Systems of innovation: handbook of the economics of innovation. In B. Hall, & N. Rosenberg, *Handbook of the economics of innovation* (Vol. 2, pp. 1159-1180). Amsterdam, The Netherlands: North Holland.

Teece, D. J. (2014). The foundations of enterprise performance: Dynamic and ordinary capabilities in an (economic) theory of firms. *Academy of Management Perspectives*, *28*(4), 328-352.

Tidd, J., & Bessant, J. (2013). *Managing innovation: integrating technological, market and organizational change* (5a ed.). New York, NY: Wiley.

World Economic Forum. (2019). *The Global Competitiveness Report 2015-2016.* Geneva, Switzerland: Author.

Carlos Ivan Simonsen Leal

https://orcid.org/0000-0002-4304-2847

President of the Fundação Getulio Vargas since 2000. Civil Engineer, he graduated in 1980 from the School of Engineering of the Federal University of Rio de Janeiro (UFRJ), and chose the academic life obtaining, in 1982, a master's degree in Mathematical Economics from the Institute for Pure and Applied Mathematics (Impa), a doctorate degree from the Brazilian School of Economics and Finance of the Fundação Getulio Vargas (FGV EPGE) (1980-1982), and a Ph.D. in Economics from Princeton University (USA) in 1986. He was a professor of Macroeconomics, Microeconomics, and Public Finance at the FGV EPGE in 1986. Professor Simonsen Leal was a consultant for the Central Bank of Brazil in 1989, and held different positions at FGV: Dean of FGV Business, 1992-1994; Dean of FGV EPGE, 1994-1997, and Vice-president of FGV, 1997-2000. In 2002, he was awarded the title of Grand Cross of the National Order of Scientific Merit by the President of Brazil, for his contribution to Science and Technology. In 2008, he was granted by the Republic of France with the *Palmes Académiques*. Other honorific titles and awards received include the Judicial Medal awarded by the Court of Justice of the State of Rio de Janeiro (2009), Professor Emeritus of the Army Command and General Staff College, Peacemaker Medal of the Brazilian Army (2010), Order of Naval Merit (2013), Titular member of the Brazilian National Academy of Engineering (2013), Honorary Submariner Certificate (2013), Eminent Engineer Diploma from Polytechnic School (2014), Merit Medal "Tamandaré" (2014), Diploma of Aeronaval Merit (2016), Medal of Statistical Merit "Mário Augusto Teixeira de Freitas" (2016) from the Brazilian Institute of Geography and Statistics, Medal of the Brazilian Army (2017), Honorary Hydrographer from the Brazilian Navy (2017), Medal of the Order of Military Merit awarded by the Brazilian Army (2018), Order of Naval Merit awarded by the Brazilian Navy (2019), and Commendation of the Order of Aeronautical Merit (2019).

Paulo N. Figueiredo

https://orcid.org/0000-0002-5857-8126

Full professor of technology and innovation management of the Brazilian School of Public and Business Administration (EBAPE) at the Getulio Vargas Foundation (FGV), Brazil; He holds a Ph.D. in science, technology and innovation policy studies from the University of Sussex, Science Policy Research Unit (SPRU), United Kingdom; Senior Research Associate, University of Oxford, United Kingdom; Researcher, Brazilian National Council for Scientific and Technological Development; He is the founder and editor-in-chief of the *International Journal of Technological Learning, Innovation and Development*, United Kingdom; In 1999, he set up – and still heads up – the Research Programme on Technological Learning and Industrial Innovation in Brazil at FGV EBAPE. Site: www.ebape.fgv.br. E-mail: paulo.figueiredo@fgv.br