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Article

National innovation strategy: A brief contribution to its effectiveness from the perspective of technological capability accumulation[1]

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Technological capability refers to knowledge-intensive skills and resources to change existing technologies or to create new ones. The accumulation of such capability by companies and industries has been part of governments' and businesses' agendas as it is vital for countries' industrial development and increase of per capita income. However, the various public innovation policies implemented in Brazil over the last few decades and the different studies and debates on their limited outcomes failed to address the accumulation of technological capabilities by companies and industries as one of the primary sources for the increase in the rate of innovation and the sustained growth of the economy. This article presents an analytical framework to contribute to the effectiveness of a national innovation strategy centred on the accumulation of technological capability at the level of companies and industries. This analytical framework can contribute to assessing the return on public innovation policies regarding the accumulation of technological capability to develop significant innovations.

Keywords: public innovation policy; technological learning; industrial development; socioeconomic development; technological capability.

Estratégia nacional de inovação: uma breve contribuição para sua efetividade sob a perspectiva de acumulação de capacidade tecnológica

A acumulação de um conjunto de habilidades e recursos intensivos em conhecimento para mudar tecnologias existentes ou para criar novas tecnologias, ou seja, a capacidade tecnológica, em nível de empresas e indústrias, é um dos insumos vitais para a transição de países para níveis progressivamente mais elevados de desenvolvimento industrial e de renda *per capita*. Esse tema tem integrado a agenda governamental e empresarial de vários países que realizaram essa transição de maneira exitosa. Porém, as diversas políticas públicas de inovação implementadas no Brasil durante as últimas décadas, assim como os diferentes estudos e debates sobre os resultados limitados gerados por essas políticas, têm dispensado um tratamento limitado à acumulação de capacidade tecnológica de empresas e indústrias como uma das fontes primárias do aumento da taxa de inovação e do crescimento sustentado da economia. Este artigo objetiva apresentar uma base analítica no intuito de contribuir para a efetividade de uma estratégia nacional de inovação centrada na

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acumulação de capacidade tecnológica em nível de empresas e indústrias. Essa base analítica pode contribuir para a aferição do retorno das políticas de incentivo à inovação em termos de acumulação de capacidade tecnológica para inovações significativas.
Palavras-chave: política pública de inovação; aprendizagem tecnológica; desenvolvimento industrial; desenvolvimento socioeconômico.

Estrategia nacional de innovación: una breve contribución a su efectividad desde la perspectiva de la acumulación de capacidad tecnológica

La acumulación de un conjunto de habilidades y recursos intensivos en conocimiento para cambiar las tecnologías existentes o crear nuevas tecnologías, es decir, la capacidad tecnológica, en el ámbito empresarial e industrial, es uno de los insumos vitales para la transición de los países hacia niveles cada vez más altos de desarrollo industrial y de ingreso per cápita. Este tema ha integrado la agenda gubernamental y empresarial de varios países que hicieron exitosamente esta transición. Sin embargo, las diversas políticas públicas de innovación implementadas en Brasil durante las últimas décadas, así como los diferentes estudios y debates sobre los limitados resultados generados por estas políticas, han dado un tratamiento limitado a la acumulación de capacidad tecnológica por parte de empresas e industrias como una de las fuentes principales del aumento de la tasa de innovación y del crecimiento sostenido de la economía. Este artículo tiene como objetivo presentar una base analítica para contribuir a la efectividad de una estrategia nacional de innovación centrada en la acumulación de capacidad tecnológica en el ámbito empresarial e industrial. Esta base analítica puede contribuir a la evaluación del retorno de las políticas de incentivos a la innovación en términos de acumulación de capacidad tecnológica para innovaciones significativas.
Palabras clave: política pública de innovación; aprendizaje tecnológico; desarrollo industrial; desarrollo socioeconómico.

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1. INTRODUCTION

The accumulation of a set of knowledge-intensive skills and resources to change existing technologies or to create new technologies, that is, technological capability at the level of companies and industries, is one of the vital inputs for the transition of countries to progressively higher levels of industrial development and per capita income (Bell & Pavitt, 1993; K. Lee, 2019; Nelson, 2007).

Over the last 60 years, especially since the early 2000s, Brazil has implemented several public policies related to innovation to promote socioeconomic development. However, although meritorious, such initiatives have been insufficient to materialise the desired objectives. Brazil's growth and socio-economic development have been limited, among other factors, by its systemic insufficiency of the capabilities to manage and generate significant innovations at the level of companies, industries, and the economy.

Brazil's insufficient capability for innovation is reflected on several fronts: in its high production costs, in the low added value of its exports, in the country's growing technological insignificance on the world stage coupled with the worrying condition of being, with some exceptions, a mere passive user of imported technologies, in the poor service by the public sector to the demands of the population and the anachronistic practices present in the daily lives of various economic activities (Figueiredo, 2023; Leal & Figueiredo, 2021).

On the other hand, in recent years, there have been several studies and debates about Brazil's low rate of innovation and the ineffectiveness of related public policies. However, the accumulation of technological capability at the level of companies and industries, although being a primary source of innovation and economic growth (Aharonson & Schilling, 2016; Gräbner & Hornykewycz, 2022; K. Lee, 2013), has been neglected in the existing public policies and related studies and debates. Therefore, building a national innovation strategy centred on accumulating progressively higher levels of technological capability in companies and industries is imperative.

This article aims to provide some inputs for designing a national innovation strategy centred on accumulating technological capability at the level of companies and industries. This analytical framework can also contribute to assessing the return of innovation policies regarding the accumulation of technological capability for significant innovations. To achieve this objective, the next section discusses the economic relevance of accumulating technological capability for innovation in companies and industries. The third briefly discusses the imperative of an effective national innovation strategy from the perspective of the accumulation of technological capability. The fourth presents an analytical framework to assist in designing and implementing a national innovation strategy. Finally, the fifth presents the final considerations.

2. ECONOMIC RELEVANCE OF INNOVATION AND TECHNOLOGICAL CAPABILITY AT THE LEVEL OF COMPANIES AND INDUSTRIES

One of the main reasons for slow growth in certain emerging economies is the lack of technological capability for innovation by companies and industries (K. Lee, 2013). This reflects the historically determined condition of companies in emerging and middle-income economies and their late industrialisation process, associated with low learning opportunities to accumulate technological capabilities for significant innovations (Bell, 2009; Mathews, 2002) and recurrent failures of public policies (Bell, 2009; Bell & Pavitt, 1993, 1995; K. Lee, 2019; K. Lee, J. D. Lee, Meissner, Radosevic, & Vonortas, 2021).

To increase the economy's innovation rate and compete in global markets, companies from emerging economies must accumulate innovative capability at a level close to, equal to, or superior to that of global technological leaders in advanced economies (K. Lee & Mathews, 2012). However, the effectiveness of this process depends, to a large extent, on deliberate efforts at the level of companies and industries, with government support, to acquire and generate knowledge, that is, to engage in technological learning processes for the construction and accumulation of technological capabilities for innovation (Bell & Pavitt, 1993; Chung & K. Lee, 2015; Lall, Navaretti, Teitel, & Wignaraja, 1994; Nelson, 2007).

Sustained national economic growth depends, to a large extent, on adding value to national production (Cimoli, Dosi, & Stiglitz, 2009; Dosi & Yu, 2018; K. Lee et al., 2021), which largely depends on the innovation capability of companies and industries (Aharonson & Schilling, 2016; Bell & Pavitt, 1993; Gräbner & Hornykewycz, 2022; Teece, 2014). Specifically in emerging and middle-income economies, the achievement of a per capita income level close to or equal to that of industrially advanced and high-income economies reflects, to a large extent, the narrowing or widening of the gap in technological capability for innovation in relation to global industry

technological leaders located in advanced economies (Bell & Figueiredo, 2012; K. Lee, 2013; Malerba & Lee, 2021).

Brazil is a late-industrializing and middle-income economy, a condition in which it has been parked for over 50 years. Countries in such condition are trapped between two aspects: on the one hand, their production costs are too high, preventing them from competing with the most exporting and competitive economies; on the other hand, their level of technological capability for innovation, specifically at the level of companies, is not high enough to compete with advanced economies. In this condition, nations that stagnate for a long-time experience slow economic growth, with their social ills (K. Lee, 2019; K. Lee et al., 2021).

Countries that managed to escape from this condition of middle income and technology achieved a considerable increase in productivity gains in the economy, which was achieved, in large part, by increasing the technological capability for innovation in different industrial sectors and by exposure to international competition (K. Lee, 2019, 2013; Yeon, Lee, & Baek, 2021). In other words, they considerably strengthened their competitiveness, which also reflects the accumulation of technological capability for innovation at the industry and company levels (Cimoli et al., 2009; K. Lee et al., 2021); after all, it is in the industry and its companies, with the support of partner organisations and the government, that the transformation of creative ideas into wealth takes place. Put differently, it is at the industry and company level that the real innovation process takes place (Bell & Figueiredo, 2012), as will be discussed later.

At this stage, however, it is important to stress that such a statement does not suggest that innovation in other areas of the economy is not important. For instance, public sector innovation can significantly impact society by improving public services, healthcare, education, and infrastructure and addressing complex societal challenges, including climate change, poverty, and public health crises. Nevertheless, innovation in the private sector is directly related to economic growth by creating new products, services, and markets, which stimulate job creation and increase overall prosperity. Additionally, private sector innovations often directly benefit consumers through improved products, lower prices, and increased choice. Consequently, this article focuses on technological capability accumulation for private-sector innovation.

Technological capability and innovation are not a cure-all or a panacea for industrial and socio-economic development. However, evidence throughout history shows that countries that have accumulated technological capabilities for significant innovations in various industry segments have also effectively transitioned to higher industrial, technological and, mainly, per capita income levels (Dosi & Yu, 2018).

Nevertheless, increasing the rate of innovation in Brazil to enable the country to add more value to its production and obtain sustained economic growth depends on overcoming several national difficulties, some structural, such as the high concentration rate of the Brazilian economy (Leal & Figueiredo, 2021) and other problems that constrain innovation performance (Mazzucato & Penna, 2016). Successful countries in the transition to a higher level of industrial development and per capita income made significant efforts to overcome structural difficulties, such as quality of education, infrastructure, tax system, and economic competition.

The solution to these problems is a necessary, but not sufficient, condition for a successful transition to a higher level of industrial and socioeconomic development. Therefore, specific efforts are needed to accumulate high technological capabilities in companies and industries, vital sources of innovation and sustained economic growth (Bell & Figueiredo, 2012; Fagerberg, Mowery, & Nelson, 2005; K. Lee, 2013, 2019).

3. IMPERATIVE OF A NATIONAL INNOVATION STRATEGY CENTRED ON THE ACCUMULATION OF TECHNOLOGICAL CAPABILITY

Brazil has made significant efforts to innovate over the last 60 years, especially in the last two decades. For example, since 1999, the country has consistently increased investment in research and development (R&D), which encompasses basic research activities, applied research and development of products and processes, as well as solutions to various technological problems (Figueiredo, 2023; Leal & Figueiredo, 2021).

According to Silva (2018), from the beginning of the 2000s, there was a significant increase in innovation-oriented policies at federal, state and municipal levels – from 2011 to 2020, 36 innovation policies were implemented at the federal level. Since 2010, several versions of formal initiatives have been generated, such as the National Science, Technology, and Innovation Strategy (2012-2016, 2015-2020, 2016-2022) and the National Innovation Policy accompanied by the National Innovation Strategy. These documents have worthy intentions and define guidelines for scientific-technological and innovation activities for national development.

Despite the intensity of public innovation policies in Brazil during the last decades, the innovation rate, productivity, and competitiveness results have been limited. Except for a few areas, Brazil has experienced a systematic distancing from the international frontier of technological innovation (Leal & Figueiredo, 2021).

Several studies have examined and discussed some of the inconsistencies and paradoxes of Brazil's initiatives to promote innovation in the economy from different perspectives and methodologies. For example, Carrara and Ferreira (2020) argue that, although R&D spending has grown, it is still insufficient to robustly promote the country's economy (Carrara & Ferreira, 2020). Bastos and Frenkel (2017) highlight the discrepancy between scientific production and patent application, while Mazzucato and Penna (2016) examine the strengths and weaknesses of the Brazilian innovation system. They draw attention to the lack of a long-term agenda and the low demand from the private sector for knowledge produced in the public sector.

Reynolds, Schneider, and Zylberberg (2019) examine Brazilian innovation initiatives from different angles, such as the political economy of innovation, the creation and diffusion of knowledge and institutional innovations, and the activities of companies and industries in the face of the global economy. They highlight the need for the private sector to take the lead in innovation initiatives in Brazil and the urgency for focus and robust evaluations of innovation programmes and policies in the country.

Another group of studies examines the returns obtained by specific innovation policies. However, although careful and robust, their analyses generate inconclusive and non-convergent results. For example, in 2005, Law No. 11,196 (Lei nº 11.196, de 21 de novembro de 2005), was enacted, known

as the Good Law. Its objective is to induce business investments in R&D by granting federal tax incentives, hiring researchers, and introducing new products/services and processes into the market. Investments made through the tax incentives of this law represent around 36% of total investment in R&D in Brazil (Araújo, Rauen, & Zucoloto, 2016).

Some studies sought to identify the impacts of the Good Law on the Brazilian economy and found, for example, an increase in investments in R&D by companies (Colombo & Cruz, 2018; Kannebley, Shimada, & De Negri, 2016) and a greater probability of innovating (Santos et al., 2020). On the other hand, other studies argue that these expenditures did not result in more innovation (Rocha & Rauen, 2018). Inconclusive analyses and divergent perspectives also appear relative to other innovation policies, such as the Inovar-Auto Programme (2013-2017). This public policy aimed to encourage increased nationalisation of vehicles consumed in the country and increase the international competitiveness of this industry through the development and training of suppliers and investments in R&D, involving a tax expenditure of approximately R$7 billion.

When examining the National Innovation Strategy, De Negri et al. (2021) point out some threats to its effectiveness, including the lack of precise diagnoses and clear objectives, broad and unattainable goals, fragmentation, and lack of priorities. Thus, the Federal Audit Court (TCU [in the Portuguese acronym], 2022), when examining the effectiveness of public innovation policies, found:

> "[...] flaws in the entire cycle of public policies on Science, Technology and Innovation (ST&I) that can compromise the transformation of scientific advances into gains in productivity and competitiveness for the country."

In addition to corroborating the deficiencies identified by De Negri et al. (2021), the TCU (2022) draws attention to the absence of long-term strategic planning, to inefficient tax benefits to induce the competitiveness of incentivised companies and products, as well as the lack of goals and indicators of results and impact.

In sum, over the last few decades, especially in recent years, there has been a profusion of initiatives in debates, proposals, government documents and studies from different perspectives and methods related to innovation policies in Brazil. However, in most of these initiatives, accumulating technological capability at the level of companies and industries has been surprisingly neglected, even though it is a primary source for innovation and sustained economic growth, as discussed previously.

The same occurs in debates about the reindustrialisation of Brazil, which has been treated as a key to sustainable economic development. Although "technology" and "innovation" appear frequently in this debate, the accumulation of technological capability for innovation in companies, industries and their ecosystems has not received adequate attention. Reindustrialisation is a complex process and involves multiple factors, but the effective accumulation of technological capability for significant innovations at the level of companies and industries is a fundamental condition for industrial development (Bell & Figueiredo, 2012; K. Lee, 2013). In other words, despite its fundamental importance, the process of accumulating technological capability for innovation, its sources, and its impacts at the level of companies and industries have been neglected in government documents and debates on innovation and reindustrialisation policies in Brazil.

Therefore, it is imperative to design and implement a national innovation strategy emphasising accumulating technological capability for innovation. The next section introduces an analytical framework that contributes to the effectiveness of the design and implementation of this strategy.

4. ANALYTICAL FRAMEWORK FOR A NATIONAL INNOVATION STRATEGY CENTRED ON THE ACCUMULATION OF TECHNOLOGICAL CAPABILITY

The analytical framework herein identifies technological capability accumulation and innovative activities as central variables. Deliberate investments in knowledge acquisition processes from external and internal sources are considered primary inputs for accumulating technological capability. The analytical framework also identifies the impacts of accumulating technological capability and implementing innovative activities. This section presents the definitions and operationalisation of the main components of the analytical framework.

4.1. Innovative activities: Meaning and properties

It seems like a truism or cliché to argue about the importance of innovation for the sustained growth and competitiveness of companies and countries. However, managing the innovation process and the main source for innovative activities, technological capability, is far from trivial. For example, surveys carried out by consultancies, such as McKinsey and Deloitte, among international executives show that, although most managers recognise the importance of innovation, they have difficulty managing it (Blackburn, Galvin, LaBerge, & Williams, 2021). One of the problems refers to the confusing understanding of its real meaning. Although it may seem obvious, the meaning of the term "innovation" is unclear to many business and government managers. Sometimes, innovation is defined very narrowly; in others, it is confused with invention, creativity, technology, and science. Therefore, discussing some aspects of innovative activities' real meaning and properties is relevant.

4.1.1. Innovation: its real meaning and some requirements

The term "innovation" comes from the Latin *innovare,* which means to do something different. From an economic perspective, innovation means adding value to a creative or inventive idea. Although creativity is inherent to all innovative activity, it is a necessary but insufficient condition. Likewise, an invention reflects a creative idea, sketch, or model for a new or improved device, product, process, or system, which can be patented but does not necessarily result in innovation. There is a chain of events from invention to its specification or application as an innovation, often involving a long and risky path (Fagerberg et al., 2005). Therefore, inventions involving great technical-scientific sophistication and creativity cannot be confused with innovations.

Some interrelated requirements must be met to classify an activity as innovation. The first of these refers to novelty, which can be relativised. According to the Oslo Manual (Organization for Economic Cooperation and Development [OECD], 2005), we can have innovations that are new to the company or organisation, new to the market or local economies and new to the world. New-to-

business innovations are typical of developing economies. They reflect basic incremental innovations or creative imitations but can be a basis for evolution to more sophisticated innovative activities.

Although it is argued that innovation only happens with its first introduction into the socioeconomic system, this is related to another important requirement that involves practical application and added value. An innovation meets an existing or potential demand – a demand is created for an unknown benefit. This means demonstrating differentiation regarding what exists and/or generating some benefit that is not yet delivered by what exists. Such added value can be reflected in a greater degree of satisfaction perceived by users of products, services and/or industrial processes regarding increased efficiency, productivity, safety, comfort, practicality, etc.

4.1.2. Innovation: non-linear process essentially led by companies

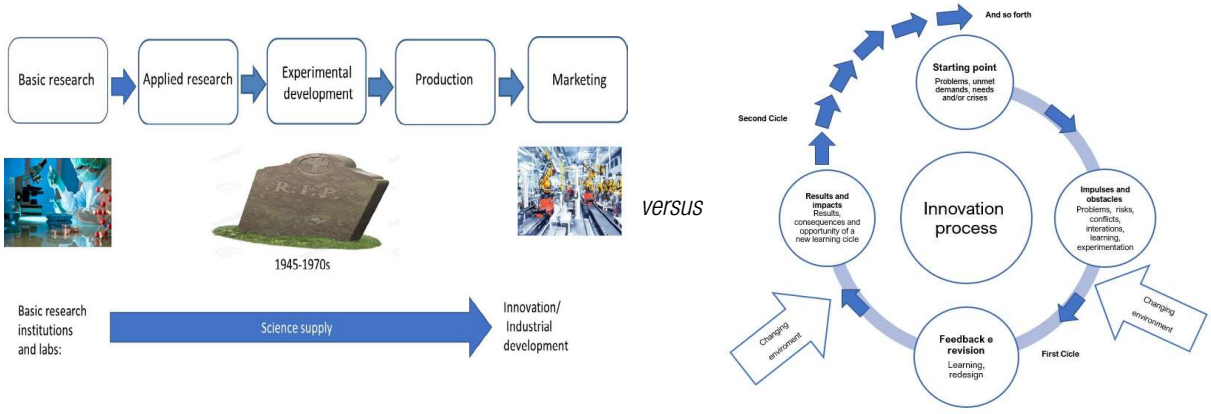
Innovation is a process, but not a linear process. Intarakumnerd and Chaminade (2011) argue that the few developing countries with innovation policies often reflect innovation as a linear process. In other words, they tend to encourage the development of basic research capabilities in the public sector (universities and research institutes), neglecting the accumulation of technological capacity in the private sector. From this perspective, industry, in a broad sense, and companies are seen merely as users of the national science, technology and innovation system.

Private investment in innovation, including R&D, guarantees adherence to demands, forcing a greater focus on results. Companies accumulate specific and idiosyncratic experience and knowledge about technical aspects of products, processes, and services and their commercialisation. Furthermore, innovations in companies and their network of partners in various sectors of the economy are the framework for productivity and growth in countries, reiterating what was discussed in the previous section.

Considering that the innovation process is implemented primarily by companies (Fagerberg et al., 2005), productivity gains and economic growth in countries ultimately depend on innovative companies (Bell & Figueiredo, 2012; K. Lee, 2013). However, public innovation policies in developing countries tend to neglect the company's primary role as a demander for qualified human resources and different types of knowledge to solve problems or meet existing and potential demands. In this context, there is a tendency to mistakenly attribute to universities and public research institutes a role in concentrating basic research and generating innovation.

This linear perspective argues that innovation would be a process that begins with basic research, evolving, sequentially, to applied research, development, production, and commercialization, as represented by the left side of Figure 1. This point of view, which emerged around 1945, was widely questioned and lost its validity in the 1970s. Based on empirical observations, the innovation process began to be understood as recursive, full of interactions and influences, back and forth welcome (Fagerberg et al., 2005), as represented on the right side of Figure 1.

FIGURE 1 INNOVATION PROCESS: LINEAR PERSPECTIVE *VS.* NON-LINEAR PERSPECTIVE



Source: Elaborated by the author and adapted by Haapala (2019)

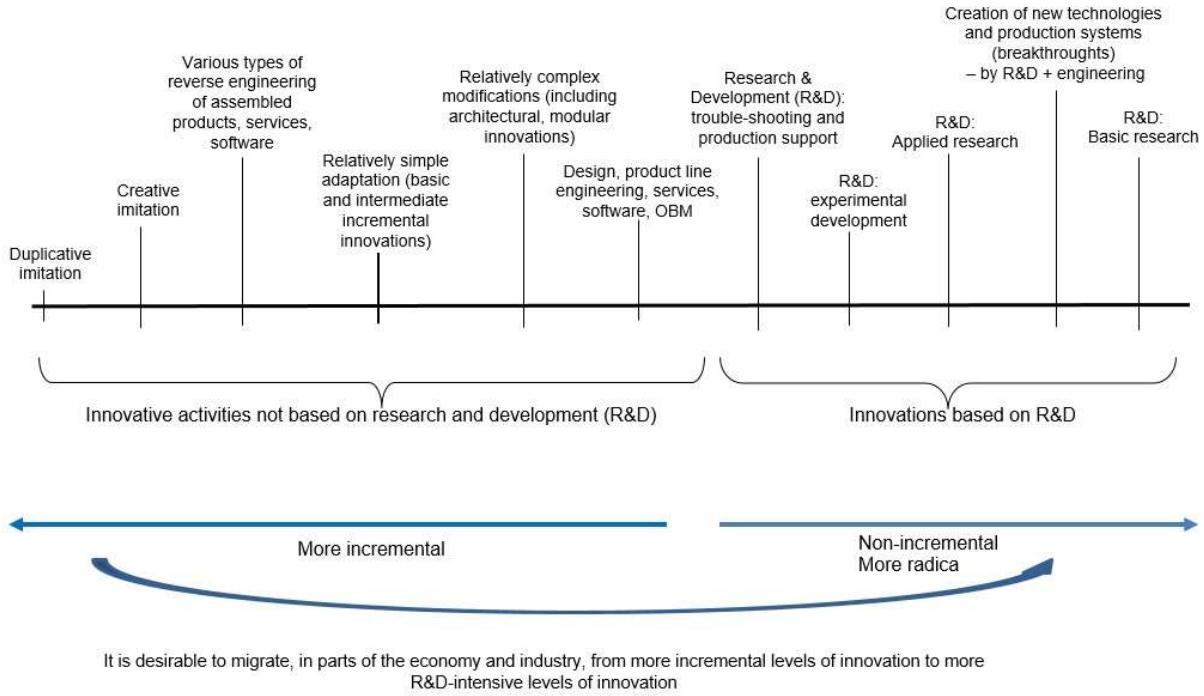
From the 1960s onwards, when science, technology, and innovation (ST&I) policies were institutionalised in the national development model, they were also conceived and implemented from a linear perspective, with an emphasis on training human resources to be absorbed by academia and an emphasis on basic research, concentrated in universities and public research institutes. At the beginning of the 2000s, technological research, that is, activities of an experimental nature, development, and prototyping, that is, R&D activities more associated with industry demands, began to receive greater attention in programmes and funding for innovation in Brazil (Vedovello, 2021). However, a large part of national R&D continues to be centralised in the public sector, while the private sector remains a mere user and is little attracted to greater engagement. This is inverse to what has occurred for decades in advanced economies, including South Korea and China (Figueiredo, 2023; Leal & Figueiredo, 2021).

4.1.3. An expanded perspective on innovation

Schumpeter (1934) revealed that economic development is marked by qualitative changes and discontinuities driven by technological innovation in the form of new products, processes, services, organisational arrangements, and inputs for production. More than that, he demonstrated that relevant innovations largely involve recombining existing technologies. Therefore, innovation transcends the limited perspectives that equate it only with highly original and complex activities derived from scientific efforts in sophisticated basic research laboratories.

The innovations that companies implement, individually or together with their ecosystem partners, involve a wide spectrum of activities, ranging from duplicative to creative imitations, through experimentation, design, and engineering to different levels of R&D – from problem-solving and production support to basic research –, with different economic and competitive implications (Bell & Figueiredo, 2012), as seen in Figure 2.

FIGURE 2 INNOVATION FROM AN EXPANDED PERSPECTIVE



Source: Figueiredo (2015).

It is obvious, therefore, that industry and the economy should move towards intensive levels of R&D and patenting, that is, towards the right side of Figure 2. However, most companies in developing economies, like Brazil, have not yet reached a stage of intensive R&D and patent activities. Most innovative activities refer to engineering efforts, design, and related activities (non-R&D innovations). However, in many cases, these innovation activities serve as a precondition for world-class R&D activities. Therefore, in developing economies, public policies must emphasise how companies and industries can evolve from left to right along the spectrum of innovative activities in Figure 2 (Figueiredo, 2015).

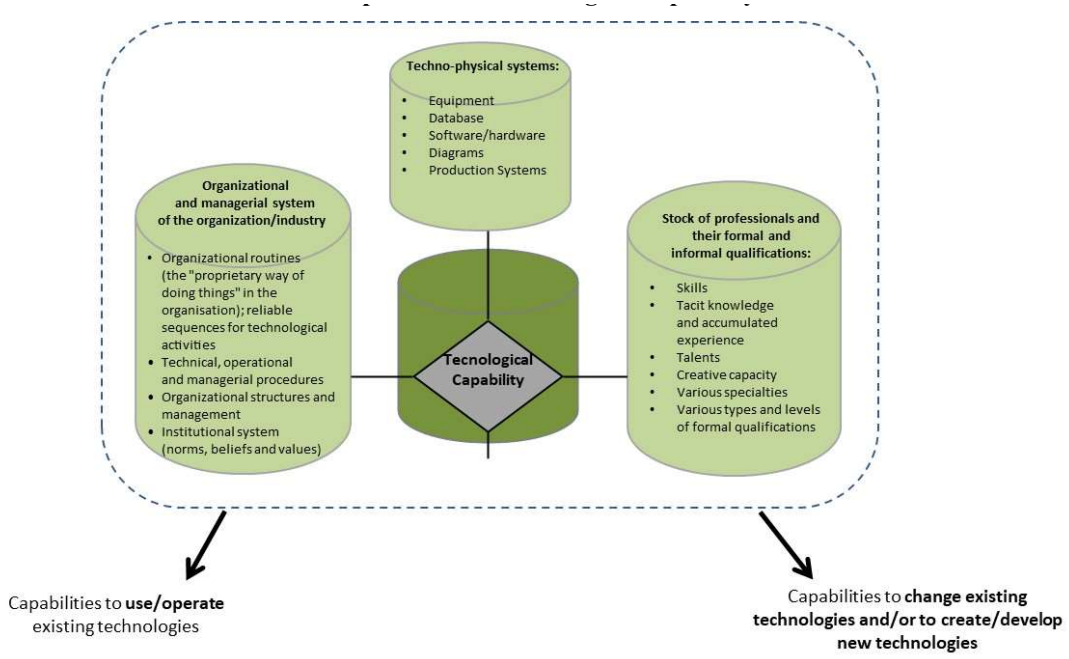
4.2. Technological capability as a vital input for innovative activities

For organisations and countries to innovate, that is, to modify existing technologies and/or develop new ones, they must build up and accumulate skills, a stock of knowledge or knowledge-intensive asset called technological capability. This asset is far from being a public good. It is highly tacit and constructed through deliberate learning processes in organisations and countries, as will be discussed in this and subsequent sections.

4.2.1. Technological capability: concept and composition

The technological capability of organisations is a set of knowledge-intensive skills and resources to use, change or create different forms of technology. It reflects what organisations can do technologically (Bell & Pavitt, 1993; Jacobides & Winter, 2012). These skills or resources are stored and accumulated in the following dimensions in organisations, as represented in Figure 3: (i) in professionals or human resources, which are not limited to scientists or researchers but also include engineers, technicians and operational professionals in the form of formal qualifications, experiences, skills and accumulated tacit knowledge; (ii) in the organisation's techno-physical systems, in the form of laboratories, databases, software, equipment, some of these systems built by professionals; (iii) in organisational structures, in the form of organisational and production processes, routines and procedures, as well as formal organisational units, such as engineering and design, quality and R&D departments, which retain a large part of professionals' tacit knowledge.

FIGURE 3 COMPOSITION OF TECHNOLOGICAL CAPABILITY



Source: Elaborated by the author.

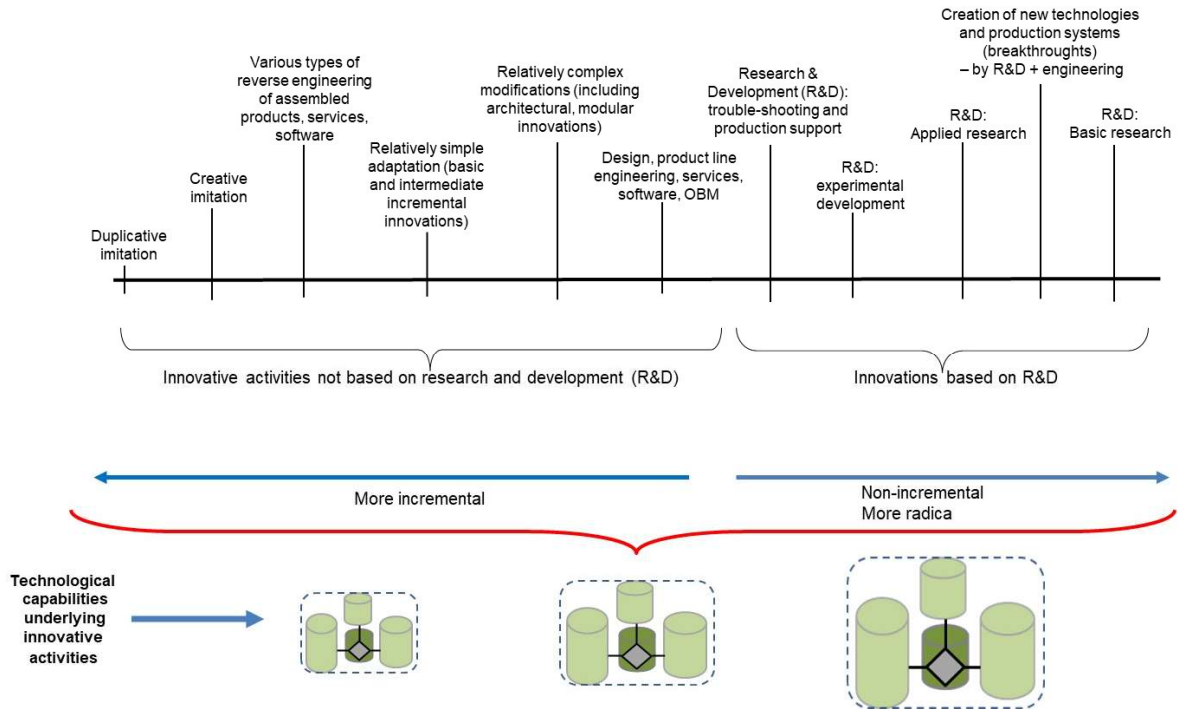
The symbiotic interaction between these three components forms an inseparable whole that constitutes a strategic asset or a stock of knowledge specific to the organisation they develop. This asset underpins implementing the organisation's technological activity and distinguishes it from others in its same area of activity (Bell & Pavitt, 1993; Dosi, Nelson, & Winter, 2000; Leonard-Barton, 1995). Part of this asset accumulates within the company, while other parts are distributed across its network of ecosystem partners (Bell & Figueiredo, 2012).

An organisation can accumulate its technological capabilities to implement operational and/or innovation activities (Bell & Figueiredo, 2012; Bell & Pavitt, 1995), as indicated in Figure 3. The first refers to the capabilities for operational activities that reflect the use or operation of existing technologies, while the second refers to the innovative capability, that is, to modify existing technologies or to create/develop new ones in various forms, such as products, services, production processes, digital systems, and business models.

Both operational and innovation capabilities include the components mentioned before (Figure 3), with differences in qualitative characteristics (Bell, 2009). Operational capabilities are fundamental to ensuring efficiency, quality and safety in a company's production processes and compliance with international standards and certifications. They can also support implementing innovation activities (Figueiredo, 2002). Therefore, there is a blurring border between them (Bell & Figueiredo, 2012).

For the organisation to grow by adding value, novelty and technology to its products and services, it is essential to engage in deliberate efforts to build up and accumulate technological capability to implement progressively higher levels of innovative activities. (Bell & Figueiredo, 2012; Figueiredo, 2015). The level of accumulated technological capability conditions this implementation. If the level of technological capability is shallow, the organisation can implement only very simple innovations with low added value and degree of novelty, as represented in Figure 4. However, as the organisation deepens its level of technological capability, it will be able to implement activities with progressively higher degrees of technical-scientific complexity and novelty.

FIGURE 4 TECHNOLOGICAL CAPABILITY AS A SOURCE UNDERLYING INNOVATIVE ACTIVITIES



Source: Figueiredo (2005, 2009, 2020, 2023).

The process of accumulating innovative capabilities, as well as the resulting innovation, is arduous and risky. Companies, in turn, are entities that accumulate and generate knowledge and learning. Specifically, they are a repository of technological capabilities from different areas of expertise (Wang & von Tunzelmann, 2000), which are accumulated in an idiosyncratic way. At the same time, companies are driven by the economic incentive to transform knowledge into practical application and wealth. Therefore, it is essential to highlight the important role of industry and companies in competitiveness, growth, and national economic development (Bell & Pavitt, 1995; Dosi, 1988; Lall, 1992).

One of the typical mistakes of public innovation policies, especially in developing economies, is to concentrate or emphasise the accumulation of these capabilities in institutions that carry out basic research, such as universities and public research institutes. This perspective excludes technological capabilities other than basic research or even technological capabilities not based on other levels of R&D. These capabilities are distributed throughout the ecosystem involving suppliers, small and medium-sized companies, consultancies, and users (Bell, 2009).

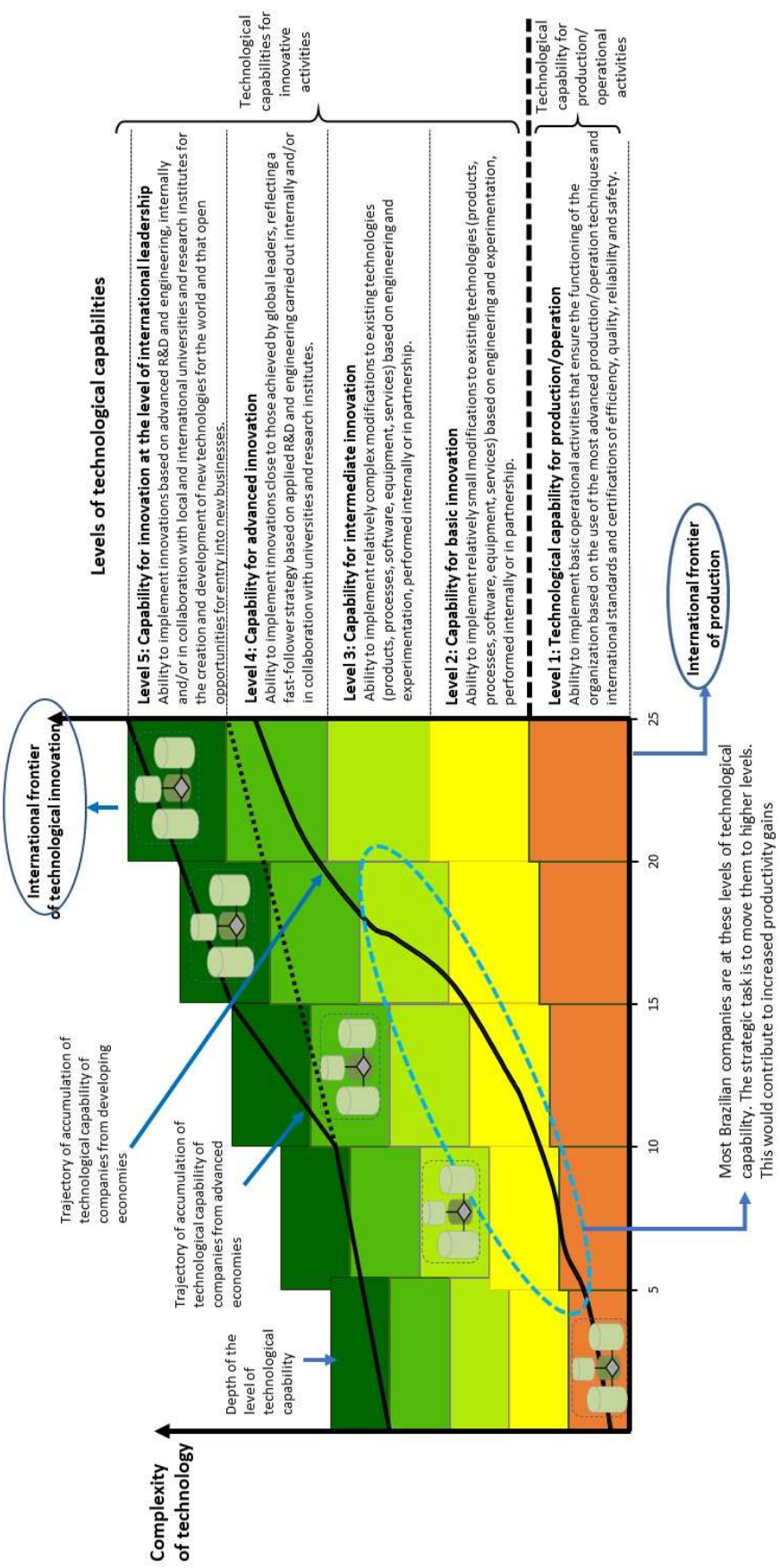
4.2.2. Operationalisation of the concept of technological capability

Examining technological capability for innovation in companies and industries tends to be carried out using standard proxies, such as patents or R&D expenditures. It turns out that these proxies have inherent limitations, as they exclude important dimensions and levels of technological capabilities (Bell & Figueiredo, 2012; Figueiredo, 2015). Overcoming these limitations, a stream of studies on the accumulation of technological capabilities and innovation in the context of developing companies and economic sectors has adopted a more comprehensive perspective from a conceptual and methodological point of view.

This perspective has been the framework of the early systematic studies on technological capability accumulation in companies from emerging economies (Bell & Pavitt, 1993, 1995; Figueiredo, 2001; Lall, 1992). This approach identifies levels of novelty and increasing significance of innovative activities. It is therefore inferred that different levels of capability underlie different types of innovative activities (see reviews on this approach in Bell & Figueiredo, 2012; Figueiredo, 2015; Peerally, Santiago, De Fuentes, & Moghavvemi, 2022).

This approach is based on the view of revealed capabilities (Figueiredo, 2011; Figueiredo & Cohen, 2019). Capabilities are revealed in the technological activities companies can carry out individually and/or in partnership with other organisations. Specifically, this approach is based on adopting a maturity model that identifies levels of technological capability, as represented in Figure 5.

FIGURE 5 MATURITY MODEL OF THE PROCESS OF ACCUMULATION OF TECHNOLOGICAL CAPABILITY IN COMPANIES FROM EMERGING ECONOMIES: AN ILLUSTRATION



Source: Adapted from Bell (1997), Bell and Figueiredo (2012), and Figueiredo (2001, 2023).

This maturity model distinguishes technological production capabilities from innovative ones, allowing them to be identified at the international frontier of production and innovation. To reiterate, technological production (or operational) capabilities refer to those that allow companies to use (or operate) existing technologies and production systems; they are the resources necessary to carry out activities to produce goods or services to a certain degree. of efficiency. Innovative technological capabilities enable companies to implement different types and degrees of innovative activities related to the resources necessary to generate and manage technological changes in terms of innovations in processes, products, technical-physical systems, services, and organisation. Innovation capabilities are disaggregated into four levels: basic, intermediate, advanced and world-leading. The last of these implies that innovation incorporates globally new characteristics in a technological area (Bell, 2009), allowing companies to explore technological activities different from existing ones (Dixon, Meyer, & Day, 2014).

Thus, this maturity model includes R&D and patents, but does not consider them unique indicators of innovative technological capability. Such a maturity model represents how companies' technological capabilities evolve systematically towards the international frontier of innovation or production. While this maturity model highlights a company's internal capabilities, it also recognises that a substantial part of its innovation capability resides in other organisations, such as suppliers, consulting firms, research institutes, and universities.

To generate an effective, and not subjective, assessment of the levels of technological capability achieved by companies or industries, the application of this maturity model needs to be substantiated by concrete and convincing evidence which reflects the capability of companies to carry out a certain technological activity with a certain degree of novelty and complexity. This approach is based on directly acquiring descriptive information about the companies' technological activities. As shown in studies in which this technological capability maturity model was used (see Bell & Figueiredo, 2012; Figueiredo & Cohen, 2019; Peerally et al., 2022), it is worth reiterating that:

1) There is no linearity in the process of accumulation of these technological capabilities.
2) Technological areas within the same organisation may differ regarding the manner and pace of accumulating these capabilities.
3) The application of this model allows us to reconstruct the trajectory of technological capability accumulation and understand whether and how companies and industries have moved towards the frontier of innovation or production capabilities.
4) It is possible to identify highly important nuances to obtain a view with adequate detail and depth, which would probably not be captured by other proxies and other methods.

4.3. Learning processes as inputs for the accumulation of technological capability

4.3.1. Brief conceptual framework

As technological capability cannot be acquired automatically in the market, its creation and accumulation by organisations, ecosystems and countries depend on deliberate and costly efforts in learning processes by people and organisations (Bell & Pavitt, 1993; Figueiredo, 2003; Figueiredo & Cohen, 2019; Malerba, 1992). This process involves the acquisition of different types of knowledge from different external sources, as well as the generation of organisational knowledge aimed at creating and accumulating technological capability. It is called "technological learning" and represents the closest variable that contributes to explaining variation in technological capability accumulation.

The approach presented herein, therefore, is based on a very simple argument: if companies make limited efforts to invest in the acquisition and creation of knowledge necessary to innovate (technological capabilities), that is, if they make limited or ineffective efforts in learning processes, they will accumulate innovative capabilities in a very limited way or not at all (Bell & Figueiredo, 2012).

Considering that, in the context of developing economies, there is a systemic shortage of technological capabilities for significant innovations, managing technological learning processes becomes a strategic task for companies. Therefore, learning processes for their accumulation at the level of companies and industries should be the target of public innovation policies (Bell & Figueiredo, 2012). The effectiveness of these processes involves simultaneous efforts to acquire knowledge from external sources and generate internal knowledge (Lewin, Massini, & Peeters, 2011).

4.3.2. Operationalisation of the concept of learning processes

The operationalisation of learning processes as key sources for accumulating technological capability has generally been based on conventional proxies, such as R&D expenditure and patent statistics. On the other hand, the methodology proposed herein is based on the literature on organisational learning (Lane, Koka, & Pathak, 2006; Leonard-Barton, 1995; Zollo & Winter, 2002) and the accumulation of technological capability in companies in developing economies (Bell, 2006; Bell & Figueiredo, 2012). It operationalises learning processes based on empirically observable practices or mechanisms to acquire and assimilate external knowledge, creating knowledge internally to accumulate innovative technological capability.

These learning mechanisms can be classified into two broad types: (i) those that involve the acquisition of knowledge and other elements of technological capability from sources external to the company and (ii) those that involve the creation and acquisition of knowledge from sources internal to the company. In other words, operationalisation is based on observing various external and internal learning mechanisms (Bell & Figueiredo, 2012; Figueiredo & Cohen, 2019).

While technological capabilities constitute a stock of resources, also called cognitive or strategic assets, learning is a process of several flows of external and internal knowledge, allowing organisations and countries to accumulate technological capabilities. Table 1 identifies and details these two learning mechanisms underlying the accumulating technological capability for innovation.

External learning mechanisms involve identifying and acquiring knowledge, skills and other elements of technological capability from external sources. Through them, companies engage with other organisations in learning processes to meet knowledge demands to undertake new forms of innovation (Dantas & Bell, 2011; Mazzoleni & Nelson, 2007), in addition to learning from various partners (Lewin et al. al., 2011), reflecting the openness of external search strategies and enhancing innovative performance (Laursen & Salter, 2006).

Such mechanisms involve purposeful, organised, and effective efforts to reach, select, capture, and obtain different types of knowledge necessary for a company to build up its innovative capabilities. Importing external knowledge, using technical assistance, and promoting training abroad are possible. Other means would be systematically channelling codified external knowledge, inviting experts to conferences, etc.

BOX 1 MODEL FOR EXAMINING ORGANISATIONAL LEARNING MECHANISMS AS SOURCES FOR THE ACCUMULATION OF TECHNOLOGICAL CAPABILITY

Learning mechanisms		Examples
External learning mechanisms: Identify and acquire knowledge, skills, and other capability elements from external sources.	Hiring expertise	Recent graduates or experienced professionals engaged in innovative activities.
	Codified knowledge acquisition	Access to scientific/technical works (e.g., scientific articles, patents and engineering projects).
	Organisational arrangements for external knowledge acquisition	Organisational arrangements to acquire and access knowledge from diverse sources.
	Training with local institutions	Different forms of training (e.g., master's and doctorate) and active participation in local scientific meetings.
	Training with suppliers	Various forms of training of innovative activities.
	Learning via technical assistance	Technical assistance from specialised local companies, consultants and universities.
	Learning through users	Different types of knowledge exchange with users for problem-solving or joint development.
	Training with international institutions	Various forms of training (e.g., graduate school, advanced technician, and observation tours).

Continue

Learning mechanisms		Examples
Internal learning mechanisms: Research, experimentation and training complementing external knowledge acquisition in the development of technological capability.	R&D with suppliers	Joint R&D (e.g., *co-design* and co-development of pulp manufacturing processes).
	R&D with local institutions	Joint experiments and R&D with local universities and research institutes.
	R&D with international institutions	R&D with universities and international research institutes.
	Training and experimentation	Various forms of training (e.g., classroom and on-the-job) and experimentation (e.g., research, non-R&D and field testing, production and forestry sites, and systematic R&D) to create skills and knowledge.
	Knowledge sharing	Internal knowledge exchange (e.g., "sharing" of what may have been tacit or located in specific organisational units (e.g., formal/informal meetings, *workshops* and seminars, and multidisciplinary teams to exchange knowledge to solve/frame the company's problems/projects).
	Knowledge integration	Internal arrangements to integrate knowledge in different technology areas across the company (e.g., multidisciplinary teams, innovation committees, and company-wide projects to share and integrate innovation knowledge).
	Knowledge coding	Internal practices by which individual and organisational knowledge is accessed and disseminated to support innovative activities across the enterprise (e.g., protocols for engineering and forestry activities, internal seminars, and development of training modules by internal personnel, triggering knowledge sharing/integration).

Source: Based on Figueiredo and Cohen (2019).

Companies use internal learning mechanisms to absorb external knowledge and information, internalising them into their processes and product capabilities. This involves search, experimentation, training, and research, complementing external knowledge acquisition to accumulate technological capability, as it ensures effective absorption of externally acquired knowledge and skills, creates the knowledge base necessary for additional knowledge and skill acquisition, as well as builds an internal knowledge base to implement innovations (Bell, 2009; Lall et al., 1994). The effective use of knowledge sharing, integration and codification mechanisms is one of the vital inputs for the accumulation of technological capability for innovation (Zahra & George, 2002; Zollo & Winter, 2002).

4.4. Impacts of technological capability accumulation

The degree of complexity, added value and novelty of innovative activities implemented by companies reflects the nature and depth of their technological capability and their learning processes (Bell & Figueiredo, 2012; Bell & Pavitt, 1993; Dosi, 1988; Lall, 1992; Teece, 2014). Innovative activities

implemented through the technological capability accumulated by companies can significantly impact their performance, as innovation is one of the main ways to boost a company's competitiveness and growth. By investing in innovative activities, a company can create products, services, processes, and business models that meet customer needs in ways its competitors cannot. This can lead to significant competitive advantages, increasing market share and revenue.

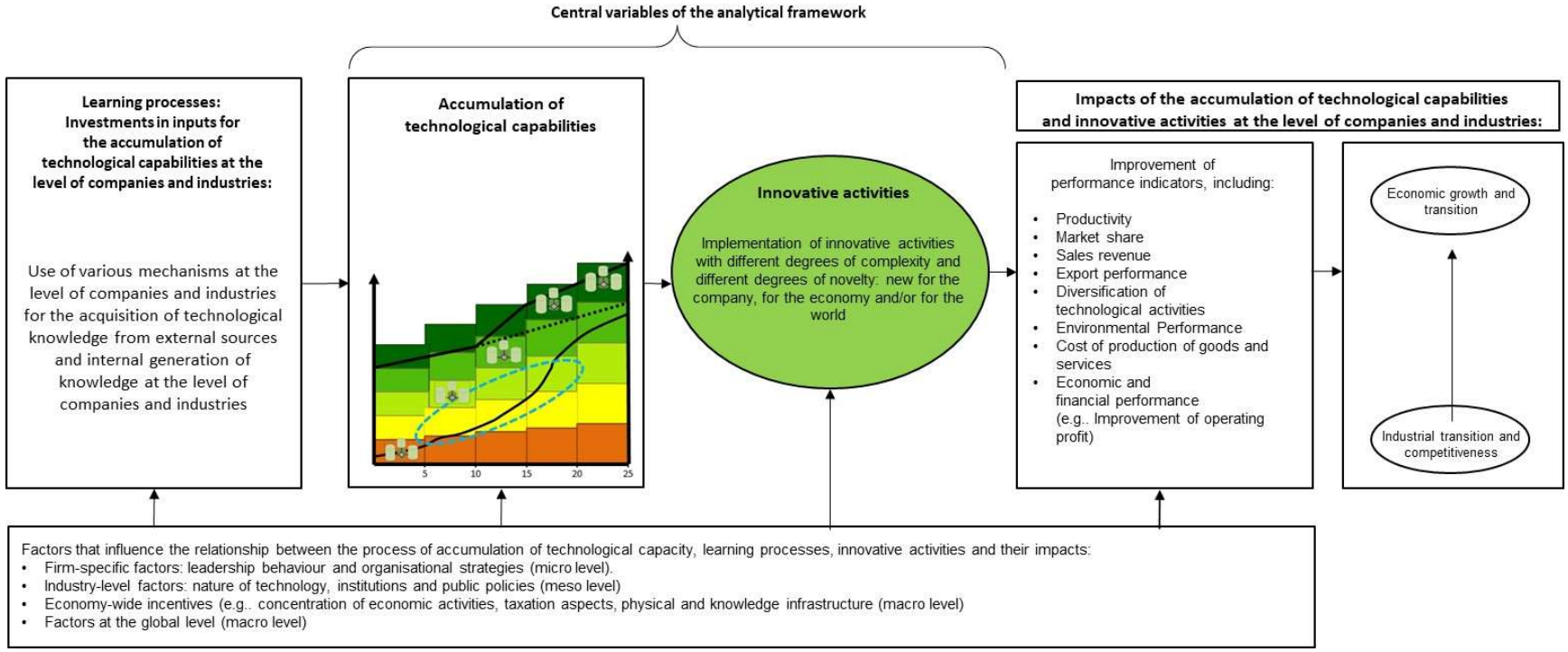
Furthermore, innovation can help improve operational efficiency, reduce costs, and increase productivity, leading to greater profitability. Innovation can also help companies adapt to changes in the business environment and face challenges such as fierce competition and changing consumer preferences.

Specifically, a company's technological capability supports the implementation of a series of innovative activities, which include duplicative or creative imitation, improvements and major changes in products or processes, designs, and engineering, as well as various levels of R&D with relevant positive impacts in operational and economic performance (Bell & Figueiredo, 2012; Bender & Laestadius, 2005; Malerba & Lee, 2021; Patel & Pavitt, 1994). In addition to innovative activities, there are also results from the accumulation of technological capability – labour productivity or gross sales revenue divided by the number of direct workers and the proportion of the company's exports in relation to gross revenue (Cassiman, Golovko, & Martínez -Ros, 2010; Figueiredo, Cabral., & Silva, 2021).

In the literature on innovation in companies from emerging economies, several studies argue that technological capability positively affects productivity and exports (Chandran & Rasiah, 2013; Krammer, Strange, & Lahitew, 2018). An inverse relationship also occurs, as the intensity of exports contributes to increasing companies' innovation capability (Rasiah, 2004). In this way, the accumulation of technological capability, especially innovative capability, impacts the attainment, sustainability, and expansion of industrial competitiveness.

As summarised in Figure 6, the analytical framework involves the relationship between the accumulation of technological capability and innovative activities as central variables, its main sources – organisational learning processes – and the impacts generated. Furthermore, the analytical framework identifies micro, meso and macro factors that can affect the relationships mentioned before, which may involve (Bell & Figueiredo, 2012; Lall, 1992): company-specific factors, industry factors, country institutions, economy-wide incentives, and global factors.

FIGURE 6 **REPRESENTATION OF THE ANALYTICAL FRAMEWORK FOR THE DESIGN OF A NATIONAL INNOVATION STRATEGY FROM THE PERSPECTIVE OF THE ACCUMULATION OF TECHNOLOGICAL CAPABILITY**



Source: Adapted from Bell and Figueiredo (2012); Figueiredo (2009, 2015, 2023), Figueiredo et al. (2021).

Factors specific to companies or other organisations involve age, size, market orientation (whether exporting or not), nationality of capital (whether local or other nationalities) and leadership style. Factors at the industry level involve the incidence and functioning of other components of the sectoral innovation system, such as aspects of technology, demand, and supply and quality of innovation support institutions – universities, education and training centres, institutes of research – as well as the quality of talent and research and studies generated by them.

Institutions and incentives at the national level include public policies related to the degree of economic competition, tax and infrastructure aspects, regulations, legal security, macroeconomic conditions and stability, and political volatility. Factors at a global level involve influences arising from global financial and economic organisations, such as the World Trade Organization, as well as international regulatory frameworks, international economic-financial and public health crises.

The effectiveness of public innovation policies and the underlying national innovation strategy aimed at the growth and competitiveness of companies and national socioeconomic development is affected by multiple factors, which can be of different levels and diverse nature. However, accumulating technological capability to implement significant innovations is a vital input for the effectiveness of national innovation strategies. Therefore, accumulating innovative technological capability is the microfoundation of economic-social growth and development.

4.5. Methodological perspectives for applying the analytical framework

It is worth commenting on the methodological strategy for implementing this analytical framework here. Most studies on innovative activities in industry and the economy tend to emphasise external sources of firm innovation, standard proxies for innovation such as R&D, and cross-sectional analyses based on significant samples of firms and data generated through national or regional innovation surveys, such as the Community Innovation Survey (CIS) and its equivalents in developing economies. This is the case, for example, of the Innovation Research (PINTEC, for the Portuguese acronym) carried out in Brazil by the Brazilian Institute of Geography and Statistics (IBGE, for the Portuguese acronym).

Despite their valuable results, such research is inherently limited, with problematic measurements (Arundel, O'Brien, & Torugsa, 2013), particularly concerning companies from countries with developing economies (see Cirera & Muzi, 2020, for a comprehensive critique). Even when these surveys are adapted for application in developing countries, questions about innovation inputs generally refer to those for implementing the innovation – for example, R&D as an internal innovation input – rather than about the sources necessary to create the company's original technological capabilities for innovation (Bell & Figueiredo, 2012).

Consequently, analyses of such data inevitably focus more on how companies use this secondary information rather than how they initially create capabilities to innovate (Bell, 2006; Bell & Figueiredo, 2012). Most studies on firm-level innovation performance in developing and emerging economies tend to replicate aggregate analyses from advanced economies based on research data on innovation and the notion of R&D as a specific and important activity source of innovation, leading to results that deviate from the technological reality of these contexts (Crespi & Zuniga, 2012).

In reality, most developing and emerging economies have a systemic shortage of technological innovation capability, a key input for innovation. Thus, most companies in these countries rarely have formal in-house R&D (Bell, 2009; Cirera & Maloney, 2017). In other words, most companies have zero R&D (K. Lee, 2013). Therefore, a broader perspective on technological capabilities (Figure 4), including non-R&D and patent capabilities, as a precondition for achieving sophisticated research-based capabilities (Bell, 2009; Bell & Figueiredo, 2012; Bell & Pavitt, 1993) has been neglected in studies on innovation performance in companies.

While the growth of studies based on Oslo Manual-type research in emerging economies has produced valuable evidence and new opportunities for analysis, they cannot be used as a substitute for other sources of evidence and types of analysis (Bell, 2006). Given the challenges of this approach in understanding relevant aspects of innovation performance in companies (Arundel et al., 2013), particularly in the context of developing economies (Bell, 2006; Bell & Figueiredo, 2012; Cirera & Muzi, 2020), Different data collection approaches and analyses must be considered (Adams, Neely, Yaghi, & Bessant, 2008). Since one approach cannot cover all economic activities, researchers must diversify their methodologies to achieve more significant studies (Holbrook & Salazar, 2004; Milbergs & Vonortas, 2005).

These limitations have been overcome by studies examining innovation performance in firms in developing economies (see Bell, 2006, 2009; Bell & Figueiredo, 2012; Figueiredo & Piana, 2021, for reviews). For example, it is worth mentioning here the study reported by Figueiredo et al. (2021), implemented based on the analytical framework presented in this article and summarised in Figure 6, to examine the effectiveness of the innovation process in 63 companies, from five industries intensive in process technology and natural resources in Brazil: steel, ethanol, cellulose and paper, mining and oil. They represent a turnover of approximately 180 billion USD, around 40% of Brazil's exports and more than 30% of the value added in Brazilian industry.

In this relevant group of companies, the study examined, over 10 years, the relationship between the accumulation of technological capability for innovation and the use of external and internal knowledge acquisition mechanisms for innovation and its impacts, in terms of labour productivity and export performance. Regarding the process of accumulating technological capability, the study revealed that:

1) 70% of the studied companies accumulated technological capability up to level 3 (capability for intermediate innovation);
2) 22% of companies have reached level 4 of technological capability (i.e., they are fast followers of global leaders);
3) 8% of companies have reached level 5 of technological capability (that is, they are capable of implementing innovations in international leadership);
4) The factors that hinder the transition of companies from level 4 to level 5 of capacity for technological innovation were examined, particularly the formation of an organisational framework for innovation.

The study found a positive and significant relationship between the accumulation of capability levels for technological innovation and the use of mechanisms for external acquisition and internal generation of knowledge for innovation. In summary:

1) Using mechanisms for internal knowledge generation contributed to a 31% increase in the level of capability for technological innovation.
2) Partnerships based on R&D between companies, universities and research institutes contributed to a 30% increase in the level of capacity for innovation.
3) The acquisition of codified knowledge and interactions with universities based on training, formal education and technical assistance were more important for companies to increase the capacity for technological innovation from level 2 to 3.
4) R&D-based partnerships with universities and research institutes were most important for accumulating and sustaining levels 4 and 5 capabilities for technological innovation.

Regarding the impacts of the process of accumulating technological capacity and learning, the study found:

1) A spectrum of innovative activities implemented by companies, from adaptations of existing technologies and innovations based on design and engineering to the most advanced levels of R&D in companies with progressively higher technological capability.
2) Average increase of 55% in productivity in the least productive companies, associated with the accumulation of levels of technological capability beyond the basic (level 2).
3) Average increase of 38% in productivity in the most productive companies, associated with increased technological capability from level 3 to 4.
4) Average increase of 37% in export performance in less exporting companies, associated with the accumulation of levels of technological capability for innovation beyond the basic level (level 2).
5) Average increase of 52% in export performance in most exporting companies, associated with the accumulation of capability for technological innovation beyond level 3.

The study demonstrated how effective efforts to accumulate capability for technological innovation generate benefits in increased labour productivity and export performance. Studies with this design and methodology can generate rich and differentiated discoveries and analyses about the real process of accumulating technological capability, its sources, and its impacts on performance. These findings would likely not be reached by aggregate studies based on standard proxies for innovative capability – for example, R&D spending and patents –, large sample sizes, and data from national innovation surveys. The type of study mentioned above, which uses the analytical framework presented in this article, offers a methodological framework for a more in-depth investigation of innovation performance in different industries. Finally, it can reveal the nature and dynamics of a micro foundation of economic growth.

5. FINAL CONSIDERATIONS

This article presented an analytical framework to contribute to the effectiveness of a national innovation strategy in Brazil focused on accumulating technological capability in industries and companies. This analytical framework can also contribute to measuring the return on public innovation policies

in terms of the accumulation of technological capability for significant innovations and competitive performance.

Despite its importance as a primary source of innovation and economic growth, the accumulation of technological capability in companies and industries has received little attention from public policies in Brazil over the last few decades, as well as from the various studies and debates that have explored the limited results generated by these public policies.

Countries that have successfully transitioned to higher levels of industrial development and per capita income have made substantial efforts to overcome structural economic difficulties, such as quality of education, infrastructure, tax system, and competition. However, the solution to these problems is a necessary but insufficient condition for a successful transition to a higher industrial and socio-economic development level. Therefore, it is necessary to emphasise the accumulation of technological capabilities for significant innovations in companies and industries, as this is a primary source for innovation and economic growth (Bell & Figueiredo, 2012; Fagerberg et al., 2005; K. Lee, 2013, 2019).

One of the conditions for this industrial and socioeconomic transition involves the progression from the accumulation of technological capability merely to use or operate existing technologies to levels of capability to significantly alter existing technologies and, mainly, to create and develop new technologies relevant to the industrial and economic fabric of the country. Evolving to progressively higher levels of technological capabilities for innovation has become more difficult, especially in emerging economies. At the same time, there is a chronic shortage of technological capability for significant innovations in this context.

Consequently, building and accumulating innovative technological capabilities throughout Brazil's industrial and economic fabric is an immense challenge. It is necessary to face multiple national structural difficulties (Leal & Figueiredo, 2021), overcoming problems concerning the management of the effectiveness of the innovation process, some of which have already been achieved by other countries. Choosing strategies and political actions is necessary to pave a feasible and viable path for this transition.

Therefore, it is imperative to build a national innovation strategy focused on accumulating progressively higher levels of technological capability in the economy. Thus, this article contributes with inputs for designing a national innovation strategy focused on accumulating technological capability in industries and companies. The article also provides inputs for measuring the return on innovation incentive policies regarding accumulating technological capability for significant innovations.

Considering that in Brazil, there has been a multiplicity of objectives related to the promotion of innovation in the country, a lack of convergence between the proposed objectives, the national difficulties in achieving public policy intentions and that many of the existing objectives have lacked a specific focus, it is recommended efforts focused on a central objective: that of substantially expanding the participation of the private sector in national investment in R&D.

Business efforts and public policies need to converge in this direction. Innovation policies involve public intervention to support the creation and accumulation of technological capability for the generation and diffusion of new products, processes or services, but also new business models and organisational arrangements, new forms of marketing and product distribution, new inputs for production, among other innovative activities.

An attempt should be made to considerably increase the participation of the private sector in national R&D investment over at least a decade. But efforts for a structural reorganisation to reverse the proportion between private and public financing of national R&D expenditure do not mean dismantling or ignoring what has been accomplished and achieved by the country in recent decades; on the contrary, it means seeking a more effective integration and rebalancing of efforts and emphasising the industry and its companies as central to the national innovation process. This reorganisation, however, will not be carried out solely by market forces. To reiterate, an intervention by State public policies is more than necessary. To achieve this, it is essential:

1) Stimulate and promote sustainable demand for innovation in the economy, particularly in companies and their ecosystems, in products, processes, services, business models and other forms.
2) Stimulate and promote the transition of companies and their ecosystems from operational technological capability or basic innovation to progressively higher levels of technological capability for innovation.

Considering the country's technological backwardness, the discrepancies between R&D expenditure, the results achieved and the national difficulties, which inhibit the innovation process, it seems unfeasible to focus on a greater number of objectives in this field. Furthermore, it also seems important to avoid enumerating diverse objectives in public policy documents related to innovation. Some objectives have appeared in public policy documents. Despite being legitimate and reflecting the best intentions of their drafters, they tend to be too numerous and diffuse, trying to cover a variety of themes and areas simultaneously. They tend to be very broad and not feasible, ignoring or underestimating the complexity and operationalisation necessary to achieve them.

Achieving the objective of increasing private sector participation in national R&D expenditure is an ambitious and complex task. This is a national effort. Consequently, achieving this objective involves interaction and synchronisation between public, economic, industrial, educational and innovation policies. Innovation policies do not work in isolation. They should not be delegated to one or two central government ministries. They need to be part of long-term economic policy, with explicit support from the federal government's leadership. In other words, innovation policies cannot be delegated to competent and well-intentioned technocrats in high positions in the state bureaucracy nor to isolated ministries or organisations. This is a theme that permeates several areas of the economy and society.

The involvement of political, government, market/industry and academic leaders is necessary. More than that, the presence and articulation of high politics become important. These are options or strategic choices that the country will have to make. Implementing such choices will require State policies, not short-term government policies.

In other words, innovation initiatives must be guided around a rationality that is much more about policy – long-term State public policies – and less about politics – policies based on partisan criteria. Seeking to achieve this central objective will come up against dozens of difficulties, obstacles, and problems, which will require enormous persuasion and negotiation skills.

The achievement of high levels of industrial and technological development in countries today considered socioeconomically advanced was marked by difficulties and obstacles. But it also involved immense determination and focus on the persistent search for the effectiveness of their efforts in creating and accumulating technological and scientific capabilities, aiming at innovations relevant to their economies and societies. The interactions between innovation, development and the economy are complex, multifaceted, and susceptible to failure. Therefore, building a national innovation strategy centred on the accumulation of technological capability and persevering in the search for effectiveness are among the fundamental conditions for Brazil to advance to higher levels of industrial and socioeconomic development.

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Paulo Negreiros Figueiredo: Conceptualization (Lead); Supervision (Lead); Validation (Lead); Visualization (Lead); Writing - original draft (Lead); Writing - review & editing (Lead).

DATA AVAILABILITY

The entire data set supporting this study's results was published in the article itself.