GLOBAL CHANGES IN PRODUCTION, DISTRIBUTION AND LEGITIMIZATION OF SCIENTIFIC KNOWLEDGE: CONSEQUENCES FOR BRAZIL

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The article aims to discuss recent changes in the way science has produced, distributed and legitimized scientific knowledge. The analysis seeks to articulate the global transformations of science with the way they have occurred in Brazil, emphasizing its own and particular characteristics. The chosen time frames bring us three different periods. The first corresponds to the post-war period and ends in the mid-1970s. The second did not end but has been gradually challenged by the phenomenon of globalization of National Innovation Systems (NIS) and the concomitant trend of internationalization of science and technology. The third time frame refers to this emergence and its meaning, still in dispute, which points to new ways of producing science.

Keywords: scientific knowledge; science, technology and innovation; global transformations of science.

MUDANÇAS GLOBAIS NA FORMA DE PRODUÇÃO, DISTRIBUIÇÃO E LEGITIMAÇÃO DO CONHECIMENTO CIENTÍFICO: CONSEQUÊNCIAS PARA O BRASIL

O artigo tem por objetivo discutir as mudanças recentes na forma como a ciência tem produzido, distribuído e legitimado o conhecimento científico. A análise busca a todo momento articular as transformações globais da ciência com a maneira como elas ocorreram no Brasil, enfatizando características próprias e particulares. Os marcos temporais escolhidos nos trazem três períodos distintos. O primeiro corresponde ao pós-guerra, e se encerra em meados da década de 1970. O segundo não se encerrou, mas tem sido paulatinamente desafiado pelo fenômeno da globalização dos Sistemas Nacionais de Inovação (SNIs) e pela concomitante tendência de internacionalizar a ciência e tecnologia tendo como princípio a competição. O terceiro marco temporal diz respeito a essa emergência e seu significado, ainda em disputa, aponta para novos modos de produção de ciência.

Palavras-chave: conhecimento científico; ciência, tecnologia e inovação; transformações globais da ciência.

CAMBIOS GLOBALES EN LA FORMA DE PRODUCCIÓN, DISTRIBUCIÓN Y LEGITIMACIÓN DEL CONOCIMIENTO CIENTÍFICO: LAS CONSECUENCIAS PARA BRASIL

El artículo tiene como objetivo discutir los cambios recientes en la forma en la que la ciencia ha producido, distribuido y legitimado el conocimiento científico. El análisis busca articular las transformaciones globales de la ciencia con la forma que han ocurrido en Brasil, enfatizando

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sus características propias y particulares. Los marcos temporales elegidos nos traen tres períodos distintos. El primero corresponde a la posguerra, y termina a mediados de la década de 1970. El segundo no terminó, pero ha sido desafiado paulatinamente por el fenómeno de la globalización de los Sistemas Nacionales de Innovación (SNIs) y la tendencia concomitante de internacionalización de la ciencia y la tecnología, que tienen como principio la competencia entre actores. El tercer marco temporal se refiere a esta emergencia y su significado, aún en disputa, que apunta a nuevos modos de producción de ciencia.

Palabras clave: conocimiento científico; ciencia, tecnología e innovación; transformaciones globales de la ciencia.

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1 INTRODUCTION

At the beginning of 21st century, the legitimacy of science has been questioned. However, its potentialities are more evident in the technological products for which it served as a knowledge base, and the scientists' career is consolidated in the great majority of the national states, with public and private resources reaching unprecedented levels in scientific activity funding. These changes cannot be understood from "within" science, but the relationship between science and other social systems, i.e., one must follow more general societal changes to understand scientific changes. Furthermore, it is necessary to consider that science is a system whose processes are strongly influenced by global dynamics, whether in research, or in how technology and innovation are based and developed.

This article aims to indicate recent changes in how science has produced, distributed, and legitimated its most valuable product, scientific knowledge. The analysis seeks at all times to articulate the global transformations in science with how they have occurred in Brazil, emphasizing its own particular characteristics. The chosen timeframe brings us three distinct periods. The first corresponds to the post-war period and ends in the mid-1970s, when science experienced its apogee in science and technology policies implemented, guided by the linear scientific and technological development model and major international projects. The second has not ended but has been gradually challenged by the globalization of National Innovation Systems (NIS) phenomenon and the concomitant tendency to internationalize science and technology based on the competition principle. The third timeframe concerns exactly this emergence and its meaning, still under dispute, and indicates new science production methods in cognitive capitalism. This moment is also characterized by the deepening of the processes of science iternationalization, regarding people, technologies, methods and institutions.

Following the cutout of the periods indicated above, the text will be divided into three parts, besides this introduction and the final notes. First, we will describe science in the postwar period, its legitimation in the cold war based on "national security policies", its increasing funding with the correlative construction of research institutes and centers, and the hiring of specialized personnel for scientific careers, both in public and private institutions. Second, we will discuss the emergence of innovation policies, and their consequence for research and development (R&D), science and technology, pointing to the development of intellectual property protection systems and the new rounds of private appropriation of scientific products. Then, we will bring the most recent debates, focusing on the emerging recognition and production methods of science and technology, in which the new information and communication technologies (ICTs) emerge.

2 THE "BIG-SCIENCE" AND THE EMERGENCE OF SCIENCE AND TECHNOLOGY POLICIES IN THE POST-WAR PERIOD

2.1 Development pattern and science in Brazil: producing science for development in the periphery

In the 1930s, a change in Latin America's development process began, particularly in Brazil. During this period, industrialization initiatives were added, and, after the Second World War, they became state policy. With the support of the Economic Commission for Latin America (Eclac), an institution linked to the United Nations (UN), created in 1948, it was a period of autonomy affirmation and of a project and a political-economic strategy creation for the region, which started to introduce ideas about science and technology as a necessity for development.

At that time, the relationship between science-industry-technology and the need for the acknowledgment of scientific activity as a source of well-being was not evident to public opinion, the business community or the government in Brazil. Much of the scientific research activity was sustained by incidental careers, whose training came from engineering or medical course, and recruitment and stability were related to family origin (Schwartzman, 1979). In other words, the few scientific institutions in Brazil selected researchers based on personal and family ties, with funding often coming from private philanthropy.

After World War II, developmental efforts focused on transforming the production structure and reducing external dependence in the region (Ffrench-Davis, 2005, p. 129). What drove the debate on economic and social development was the profound inequality between countries that industrialized and achieved high material welfare levels, shared by large sectors of the population, and those that did not industrialize and remained in poverty and with marked social inequalities. This historical moment made it seem as if the region had all

the conditions to conclude the industrialization process that had been driven by the closing of domestic markets as result of the 1930s depression, the war and the considerable foreign exchange accumulation from the previous period.

Under the strong influence of the Eclac thinkers, Latin American development was based on the perception, by the governments, of capitalist development inequality, on a world scale. It was the "cyclical centers" that imposed the unequal and hierarchical patterns of trade and development that gave rise to the system's "peripheries". According to Prebish (1949), this is the starting point to explain the form and pace of economic growth, the uneven technological diffusion, the duality between the "center" and the "periphery" and the structural unemployment conditions and wealth concentration in Latin American countries. The regional countries then began to concentrate their economic efforts on absorbing technologies capable of promoting productive structure diversification, increasing productivity and defining an investment policy that, through the State, would create the infrastructure required for this diversification.

The slower technical progress of primary products compared to industrial products leads to an increase in the latter's price when compared to the former. As Mello (1986, p. 14) explains,

> the uneven spreading of technical progress (which is seen as the essence of economic development) translates (...) into the conformation of a certain world economic structure, of a given international labor division: on one side, the center, comprising the industrialized economic group, diversified and technically homogeneous productive structures; on the other side, the periphery, integrated by economies that export primary products, food and raw materials, the central countries, highly specialized and dual productive structures.

Protectionism became an instrument for economic and technological modernization, even though it was known that the industrial production efficiency would be lower in the periphery. This was due to the understanding that inequalities were reproduced by commercial exchanges and would remain so until the industrialization process was concluded, since the very industrialization dynamics required products (capital goods) increasingly intensive in technology. In other words, the import mix would be altered, but the deterioration of trade terms would remain.

It was in the post-war period that the idea in which science and technology could generate well-being and security attained legitimacy among several national governments, mainly due to research effects, with state support, to obtain the atomic bomb, and the influence of the "Bush report", "Science, the Endless Frontier",[3] which consolidates the "linear model" of technical-scientific

3. Bush's report is the answer to the assignment made by the American president Franklin Delano Roosevelt, who had requested information about the possible role of science in "times of peace". In response, the author emphasized basic research, without concern for practical applications, which, according to Bush, would be the engine of technological progress.

development. The report, commissioned by the United States government, systematized the defense for government support for R&D activities. In Latin America, due to the debate above, scientific and technical progress was directly related to development policies and, therefore, government support for science and technology was considered as a policy to overcome the peripheral economies' relative "backwardness".

In this context of emergence for government support to science and technology, science and technology institutions and policies (STP) were created throughout Latin America. It will not be possible to describe all these initiatives in this text, but it is worth mentioning, in the Brazilian case, the creation of the Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Capes) (1951) and the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq) (1951), of the Research Support Foundations (Fundação de Apoio à Pesquisa – FAP), the entry of the Brazilian National Development Bank (Banco Nacional de Desenvolvimento Econômico – BNDE) in the financing of science and technology through the National Fund for Scientific and Technological Development (Fundo Nacional de Desenvolvimento Científico e Tecnológico – FNDCT), later managed by the Funding Authority for Studies and Projects (Financiadora de Estudos e Projetos – Finep). All these initiatives expanded personnel working in science and technology activities in Brazil, whether in universities, research centers or in R&D sectors linked to private or public companies (Morel, 1979; Schwartzman, 1979).

The public debate on science and technology was consolidated in Latin America due to the institutional changes indicated above. Issues such as science and technology "neutrality", "technique and science as ideology" (Simpson, 2015; Varsavsky, 2015; Pinto, 2005) and "national science and technology systems" (Sábato and Botana, 2015; Rangel, 2012), found good reception among intellectuals who were also interested in dependence and development topics.[4] The question now would be the search for legal and political mechanisms to integrate the scientific-technological infrastructure developed with the industrial base consolidated from the import substitution policies (Rangel, 2012). Sábato expressed this need in his famous "triangle model" (Sábato and Botana, 2015, p. 218).

> It is not enough, however, to build a strong scientific-technological infrastructure to ensure that a country will be able to incorporate science and technology into its development process: it is also necessary to transfer the research results to reality; to couple the scientific-technological infrastructure to the productive structure of society.

4. All this problematic can be articulated in a new way of thinking about science, technology and development, known as Pensamiento Latinoamericano en Ciencia, Tecnología y Sociedad (Placts).

Many difficulties were identified for the transformation of scientific knowledge, which was being generated inside the research centers, into applied research and technological innovation. Success stories were multiplying in different sectors, such as tropical agriculture, petroleum, aeronautics and nuclear energy, but, somehow, the technological gap with technologically advanced countries was identifiable, leading to the famous debate between "archaic technique" and "modern technique". The question of how to overcome the gap came to be discussed when some difficulties were encountered in the development of these policies, and here there was quite similarity between the diagnoses made.

> The most important obstacles to innovation are sociocultural (prevailing routine attitudes, lack of entrepreneurial aggressiveness, fear of union action); economic (presence of monopolized or highly protected markets, rigid marketing mechanisms, artificial price and cost structures); financial (capital scarcity and lack of existing resources optimization); political (including taxes, patent laws, labor laws, industrial promotion laws) (Sábato and Botana, 2015, p. 219).

All these diagnoses came to cast doubts on the science and technology policies implemented during that period. The fact that is not in dispute is that the debate on development and dependence in Latin America had bequeathed us an expanded scientific and technical apparatus, both in the state sphere and in the people' daily sphere, who began to recognize how important science and technology were to their lives, even if it was in the politically contaminated context of the cold war and the national security policy.

2.2 The development plans and the structuralism crisis

Of all the facts that characterized the 1970s, the one that became the trigger for the Latin American development pattern to be dismantled was the rise in oil prices, which quadrupled in 1973-1974. The oil crisis came at the moment of the Bretton Woods system collapse, undermined by the United States' unilateral withdrawal (Ffrench-Davis, 2005, p. 155) and led to an increase in other commodity prices. If for the United States this was a period of strong recession, for Brazil, however, the 1970s were a period of accelerated economic growth, industrialization, manufacturing exports and the science and technology system, already consolidated and expanding. It is worth saying that this consolidation should be seen in the above terms, of institutionalization and recognition at the state level, because, as has been said, the distancing pattern between scientific-technological and economic enterprise remained.

State planning reached its apex with the National Development Plan (Plano Nacional de Desenvolvimento – PND) and the Basic Scientific and Technological

Development Plan (Plano Básico de Desenvolvimento Científico e Tecnológico – PNBCT I and II), which programmatically recognized the relationship between technological and economic development, spending unprecedented funding amounts for science and technology activities, and technological training of national companies. However, it was observed, in unison, the low technological learning of companies and the tendency, that has always accompanied us, of technological importation. It is argued (Carlotto, 2013) that the reason for the failure is related to the lack of synchronization between science and technology policies and economic policy.

Easy and cheap access to loans in the 1970s stimulated aggregate demand, which outstripped domestic production. During the 1980s, the region was forced to adjust its aggregate demand to its spending capacity, which led to a crisis, including in science and technology. PNBCT III was presented in this crisis context, seeking to bring into the national science and technology system, directed by CNPq, "the different potentially interested agents (...) including their needs and opportunities for advancement" (Albuquerque, 2009, p. 204). A mechanism was created to identify and recruit such agents, fundamentally economic, known as Programmed Actions, which

> promoted scientific and technological knowledge democratization with actions in the most distant regions of Brazil. In other words, one of its great dimensions was to show the knowledge social meaning, removing it from elitist circles and putting it at the country's service (Albuquerque, 2009, p. 205).

For the first time, a sectorial focus was given to science and technology policy, including a comprehensive treatment of the chain of several productive segments. It must be clear that the 1980s crisis strongly affected the III PNBCT initiatives, including what was offered as "scientific knowledge democratization".

3 THE EMERGENCE OF INVOCATION POLICIES IN PERIPHERAL CAPITALISM

The economic crisis through which it passed in the 1980s led to a strong questioning of the industrial policy schemes adopted in the region, especially the promoter and regulator role played by the State, leading to the region's development model crisis in the 1990s. Much of the debate on national technology was also contaminated by comparative studies, taking the "Asian tigers" emergence as a comparative part. Freeman (1995), will contrast the Asian experience with the Latin American one, pointing to factors such as the technical change initiative based on technologies imported by the Asians, compared to the technological contribution without R&D by Latin American companies; this involved a continuous increase in business investment in R&D in Asian countries, and the opposite in Latin American countries; strong interaction between science and industry in Asia, in contrast to the weak relations between these sectors in Latin America.

By the early 1990s, *new money* was no longer available for countries affected by the crisis. Thus, programs sponsored by the International Monetary Fund (IMF) were decisive. It is important to note that the initial economic restructuring programs imposed by the IMF did not prioritize privatization, but rather stressed the need to pursue macroeconomic stability. The negative results, however, attributed to import substitution industrialization the fundamental cause of price distortions and macroeconomic imbalances. For Castellanos (1998, p. 80), this was the moment that

> State was identified as a factor to be corrected due to its "oversized" condition and its "participation" in productive activities, as well as its "deficit financing", which stimulates inflation, and therefore it was considered necessary to reduce the State through selling public companies and transferring social and infrastructure services to the private sector.

Generally speaking, the regional response to the crisis was based on recessive and administrative import control and export promotion through exchange rate policies. Such policies led, on the one hand, to strong export growth, but on the other hand, to economic stagnation and strong inflationary expansion. The long-term consequence was the reprimarization of the economies. The external adjustment interrupted, in most Latin American countries, the developmental strategy of industrialization linked to scientific and technological development.

This situation generated a considerable decrease in infrastructure investment, on one hand, and in investment in science and technology, on the other, made by the state. This situation contributed to weaken the knowledge base of a techno-productive structure that, in several sectors, some being knowledge-intensive, was in its initial stage, and a decrease in the technological learning efforts undertaken by many companies until then (Mercado, 2005).

The State modernization plans at the time highlighted the need to strengthen sectors capable of integrating into the global economy by developing the ability to compete and export, creating favorable macroeconomic conditions and stimulating export activity (Batista, 1994). They discouraged, however, the adoption of industrial policies. The economic policy then paid little attention to technological capacity development, contributing to weaken even more the technological and productive capacities of several industrial sectors, configuring a very specific pattern in productive development, based on producing *commodities* and particular forms of insertion in the international economy.

> The trend lines show a sharp decline in manufacturing activity as a component of industrial output and, to a lesser extent, in agriculture, both essential elements to any economy. However, the sectors that have shown the highest growth rates are services and mining and quarrying, in line with direct foreign investment. This

> sectoral performance allows us to speak of a dual behavior concerning the trends observed in developed countries, since they show a coupling regarding the growing participation of the tertiary sector in the GDP [gross domestic product], but a decoupling compared to the gross product evolution of natural resources exploitation activities, and in manufacturing (...)" (Mercado, 2005, p. 10).

In other words, from the economic development point of view, the country's primary-export characteristics are accentuated. Thus, unlike what happened in developed countries, which based much of their growth on manufacturing activities that add value through knowledge production, Brazil consolidates its productive model based heavily on natural resource exploitation and on basic industrial activities rather than on manufacturing (Mercado and Testa, 2003).

This economic process occurs simultaneously with universities' internationalization, on one hand, and the creation of the NIS, on the other, and has as a consequence the deepening of the disarticulation between the knowledge produced and the national development policies.

The strengthening of the Brazilian universities' internationalization process was based on an ideology about progress, according to which technology was seen as a neutral vehicle for the irreversible countries' growth (Dagnino, 2008; Lacey, 2008). From the public policy production perspective, this meant the search for increased academic productivity and placement in international rankings, more than the search for a qualitative discussion of what was being produced. According to this approach, development, understood as a one-way process, depended almost exclusively on "universal" technology incorporation, quantified according to international indicators (Carlotto and Hitner, 2019). For universities, this meant a new conception whereby the relationship between the type of knowledge developed and its impact on society becomes irrelevant, but the quantification of these elements according to indicators that measure a very specific kind of results is important.

Based on all the aforementioned, it can be concluded that the scientific and technological system in Brazil during the 20th century was institutionalized and expanded in a way that distanced it from the national capitalist dynamics, becoming basically an academic system that offered diplomas. The lack of interest by the economically advanced sectors in offering counterpart to state initiatives and in promoting R&D dynamics under their auspices contributes to this. This profound expectation asymmetry has led to the emergence of an "offerist" scientific dynamics in the scientific and technological system, "based much more on the supply of knowledge and qualified professionals by the academy than by an effective demand from the productive sector" (Dias, 2011, p. 332). Thus, the policies indicated so far, still legitimized by the "industrial society" characteristics, were unable to promote

training and technological innovation in industries, although they had achieved relative success in promoting a diversified academic system.

4 CONTEMPORARY SCIENCE AND TECHNOLOGY: THE SEARCH FOR UNIVERSITY-INDUSTRY SYNERGY

The global economic integration process had already made the point in the last quarter of the 20th century that the international competitiveness of companies would depend on factors such as science, technology and innovation. As mentioned above, the Asian economies' recent successes have caused many economic policies focused on science and technology, as new market liberalization rounds took place, to undergo transformations in which new patent policies were promoted; the investment focus shifted from the university to industry; emphasis on scientific development regarding the application context; new stakeholders in knowledge emerged, who started to actively participate in its development; new collaborative arrangements, emphasizing multidisciplinary contracts and operating in global contexts. The supposedly open patterns of scientific and technological production in the 21st century cannot be understood without taking into account the emergence of neoliberal capitalism, supposedly victorious after the 1990s.

At the beginning of the 21st century, science and technology have tightened their ties with the market, in a non-linear supply and demand dynamic, i. e., without a clear cause and consequence direction. This integration level, which is not equally noticeable in all contexts, responds, in fact, to a deepening of institutional logics already promoted in the 20th century by the national states of advanced capitalism and that, with the Asian emergence, are now being sought also by the peripheral capitalist countries. Accordingly, the "Chinese model" has relied on the relative success of policies, first copying, then technological innovation, whose recent emblem is the " 5G system" development by the giant Huawei.

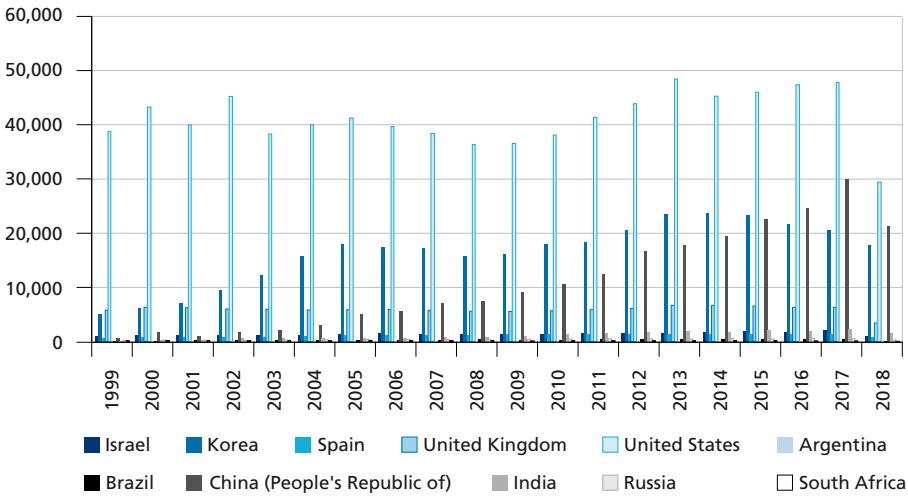
Inspired by the "white book" on science and technology (2002), which compiled the results of the *II National Conference on Science and Technology*, the science and technology policy in the beginning of the 21st century in Brazil reflected the need to transform the knowledge results into innovation, for competitiveness (of enterprises) and sustainable growth. The implemented policies focused even more on business interests, mainly in the search for a greater sector participation in scientific and technological production, relating this objective to the foreign trade and industrial policy interests as well. To this end, a number of legal-institutional reforms were implemented, starting with Act No. 110,973/2004, The Innovation Law.[5] This act indicates not only to facilitate the relationship between public research centers and companies, but

5. Updated in Act No. 13,243/2016, with Regulatory Decree No. 9,293/2018.

also "to encourage that these same public institutions become directly involved in the knowledge commercialization process, especially through patenting and licensing of new technologies" (Carlotto, 2013, p. 108). Simultaneously, Act No. 11,196/2005 – known as the "Law of Good" (Lei do Bem), consolidated tax incentive mechanisms for innovation in the productive sector.

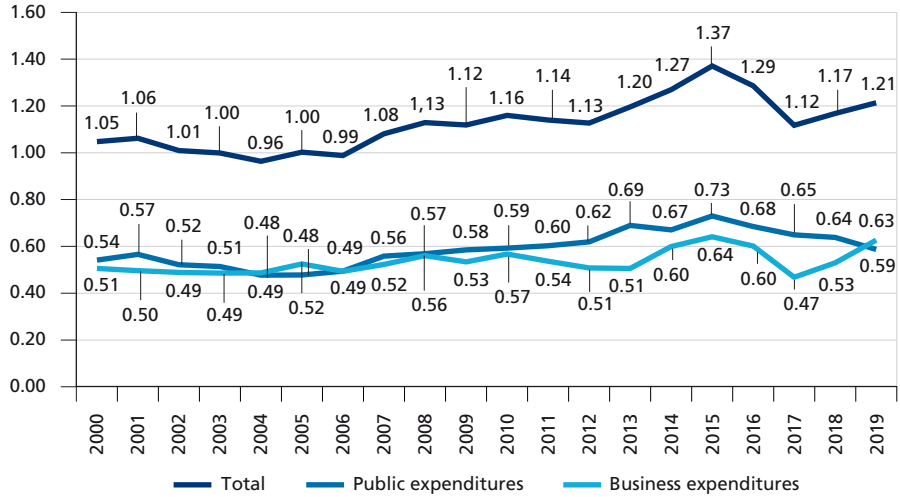
More than the legal arrangement for bringing the science and technology system closer to the productive sector, now, and opposing the industrial policy absence in the previous period, the Industrial, Technological and Foreign Trade Policy (Política Industrial, Tecnológica e de Comércio Exterior – PITCE) is also implemented, in which the expectations for technological innovation included in the implemented legal initiatives were evident, under the industrial training for the international insertion of companies. All these policies, however, seem to have been faced with deeper structural problems, as the same difficulties as in the previous period were noted at the end of the first two decades of the century, whether in the number of patents filed by companies, in the improvement of their technological capacity, in the increase in the country's technological dependence, and in public and private spending compared to other countries and previous periods (figures 1 and 2 below).

FIGURE 1
Total patent applications under the Patent Cooperation Treaty (PCT), by inventor's country of residence and priority date, selected countries (1999-2018)



Source: Organisation for Economic Co-operation and Development (OECD). Available at: <http://stats.oecd.org/Index.aspx?DataSetCode=PATS_IPC>. Accessed on: Mar. 12, 2021.

FIGURE 2
Brazil: national spending on research and development (R&D) in relation to GDP by sector (2000-2019)
(In %)



Source: Ministry of Science, Technology and Innovations (Ministério da Ciência, Tecnologia e Inovações – MCTI). Available at: <https://bit.ly/3GUnilb>. Accessed on: Feb. 10, 2022.

In this sense, the old business "bottleneck" still seems to influence the participation in R&D by companies.

> We have had a substantial growth in our participation in world publications, from 1.50% in 2000 to almost 3% by the end of this decade. However, our participation in worldwide patent deposits remains negligible and investments in research and development (R&D) as a proportion of the gross domestic product (GDP) had very modest growth. Private investment in R&D is at 0.54% of GDP (2011 data), slightly higher than at the beginning of the decade (0.49%) (De Negri, 2017, p. 25).

After all, the companies with innovative potential speech reports "excessive economic risks"; "high innovation costs"; "scarcity of funding sources"; "organizational rigidity" and "lack of qualified personnel" as elements that would hinder innovation and technological learning on their part (Mazzucato and Penna, 2016). In this regard, the reports on the innovation ecosystem in Brazil also reflect diagnoses such as the scientific and technological agenda fragmentation among the public entities involved, "including duplicated functions in several ministries, unclear competencies of the agencies, lack of synergies" (Mazzucato and Penna, 2016, p. 63), bureaucratic problems and regulatory uncertainties, autonomy and insulation of the research sector, distanced from the business sector.

Again, as was the case during the military dictatorship period, public research institutions expanded and followed the evolution of new institutional arrangements for the innovation promotion, such as technology parks, patent offices and technology transfer offices, following the funding improvements by the state, which kept resources upward and stable. This brought to an improvement in scientific working conditions in Brazil, with an unparalleled increase in the number of staff employed in scientific activities and the 13th position in indexed article publication in 2018 (Web of Science Group, 2019). De Negri and Ribeiro (2012), when researching the public research institutions infrastructure linked to the MCTI conclude that

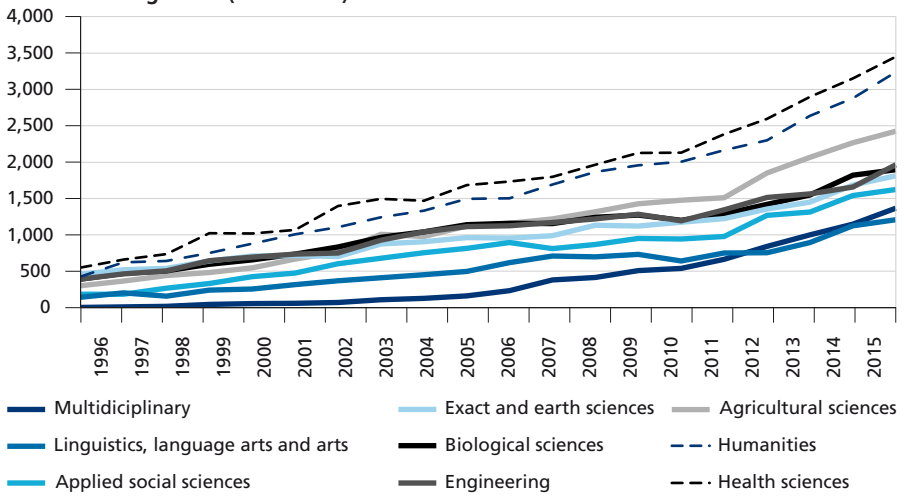
> most laboratories/infrastructures have technical capacity compatible with the best world infrastructures of its kind (...). Therefore, the data corroborate the argument that the MCTI research units have an advanced research infrastructure for Brazilian standards, which gives them a strategic role within the national ST&I system.

Mazzucato and Penna (2016), however, recognize the problems previously mentioned regarding the little synergy between public institutions of science and technology and the business sector, although they conclude that the country was able to generate an important scientific and technological infrastructure with the capacity to advance in indicators, whether in innovation or in article production. They follow, then, in the same direction as De Negri and Ribeiro (2012).

> The perception is that Brazil has developed a good science and education infrastructure and has acquired competencies in areas where it is producing frontier research, such as health (led by Fiocruz [Fundação Oswaldo Cruz] and other research centers, including universities), agriculture/food (led by Embrapa [Empresa Brasileira de Pesquisa Agropecuária]), and energy (led by the Petrobras research center Cenpes, and in the ethanol production field) (Mazzucato and Penna, 2016).

Understanding the post-graduate human resources training as an investment indicator in knowledge, it becomes clear that from the perspective of training researchers, and investment in research, the country has had, since the 1990s, policies to stimulate philosophy doctor (PhD) training and to encourage knowledge production in universities.

FIGURE 3
Number of PhD degrees awarded in Brazil, by major area and knowledge area (1996-2015)



Source: Capes Collection, 1996-2012, and Plataforma Sucupira, 2013-2015 (Capes, MEC).
Authors' elaboration.

From the chart, one can see a growth trend in the number of PhD degrees granted in the country, in all areas of knowledge, with an acceleration in 2010, especially in engineering.

Between 2009 and 2015, the PhD population has grown significantly in Brazil. In 2009, that population was made up of 98,665 individuals who had obtained one or more PhD degrees in Brazil between 1996 and 2009. In 2015, meanwhile, that population expanded, reaching the number of 187,630 PhDs. At the same time, the number of employed PhDs in that population increased in a very similar way and today reaches approximately 80% of the PhDs in all knowledge sectors with formal employment.[6]

Therefore, the Brazilian scientific and technological production context faces a challenging catastrophic economic scenario and a deep reprimarization process, associated with the increase of masters and doctors in the country. A consequence that can be observed is that, in moments of crisis, there is a tendency for researchers to leave the country and a reduction in the technological park formed, fundamental aspects of Brazil's peripheral international insertion. This is because there is a mismatch between our industrial development needs, on one hand, and the university system development, dedicated to study

6. Available at: <https://mestresdoutores2019.cgee.org.br/web/guest/estudo>.

cutting edge technologies, without worrying about the impact on the national productive network.

The university system, especially after going through an important internationalization process since the 1990s, uses imported theoretical and methodological references and research problem constructions, which makes the relationship that the university establishes with its environment complex, and often dislocated. Moreover, labor internationalization in the recent molds reinforces the brain drain phenomenon due to its typically problem-oriented training in central capitalist countries. Thus, with this resource in deficit in developed countries, especially during crisis moments, its abduction to developing countries becomes expected, as it has already happened in other historical moments. It is also clear that the migration of highly qualified human resources from relatively poorer countries to central economies is due to the limitations that a technologically dependent economy has to absorb them, much less its university system, historically suffering discontinuities in its expansion. For this reason, scientific research, university careers, and science and technology strategies and policies cannot be dissociated from the fundamental decisions of the development process.

Furthermore, brain drain can generate an atrophy of the capacities installed for development and inhibits the possibilities for the technological base to expand, as well as the innovation production in the sending country, perpetuating inequalities and the position of some countries as producers and others as science and technology consumers. After the consolidation of national S&T systems in the last 60 years around the world, including Brazil, we are now going through a moment of scientific production and personnel concentration employed in S&T activities as never seen before. With the recent cuts in investment in science and technology in Brazil, all these historic problems tend to get worse.

5 CONCLUSIONS

The Brazilian science and technology system was born international as governmental support was inspired by the global science institutionalization patterns. The support came through public policies and promotion, expressed through the creation of Capes and CNPq, and the financing by the BNDE to science and technology through the National Technology Fund (Fundo Nacional de Telecomunicações – FNT).

These initiatives expanded in Brazil the personnel employed in science and technology activities, whether in universities, research centers, and R&D sectors linked to companies, private or public, on one hand, and, on the other hand, left us with an expanded scientific-technical apparatus, both in the state sphere and

in the people' daily lives, who began to recognize the importance of science and technology for themselves.

In the 1980s, despite the previous efforts to institutionalize and expand the system, the country followed a logic of distancing itself from the national capitalist dynamics, becoming basically an academic system for diploma supply, disconnected from the national productive network, based much more on knowledge supply and qualified professionals than on the productive sector demand. The result was that, at a time when science and technology started to play a key role in global economic policies, in the Brazilian case, they were unable to promote training and technological innovation in the industries, even though they achieved relative success in promoting a diversified academic system.

At the beginning of the 21st century, although science and technology have tightened their ties to the market, they have done so without a clear cause and consequence direction. During this period, the National Science and Technology System went through a new updating process, creating a new legal framework that guaranteed, among other things, a closer relationship between science and technology and industry. This update, however, did not mean a greater technological gain or greater involvement of the business community with the science and technology produced in science and technology institutions.

Brazil has difficulties in transforming knowledge into products for the market. Despite the political and legal updating process we have gone through with the creation, among others, of the Law of Good, the Innovation Law, and the Science and Technology Legal Framework, we have not managed to take the next step towards producing shared projects between academia and industry. It is clear that a knowledge "offering" academy is not enough if other parts of the R&D process do not take place, in Brazil's particular case, scientific and technological development is not typically placed on the business community's horizon. With the recent abrupt cuts in the state funding of science and technology, bringing it back to the 1990s levels, it is noticeable that the gap that we have been talking about throughout this text between the scientific and technological and economic systems will increase. Furthermore, the search for insertion in the science and technology global standards will be compromised.

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