DISCUSSION PAPER

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INNOVATION POLICIES IN BRAZIL DURING THE 2000S: THE NEED FOR NEW PATHS[1]

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1. This paper expands on and updates parts of a recent discussion paper published by the authors in partnership with researchers from the World Bank and the OECD (Zuniga et al., 2016). Also, many of the recommendations were first published by the authors in De Negri, Rauen and Squeff (2018) in Portuguese.
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DISCUSSION PAPER

A publication to disseminate the findings of research directly or indirectly conducted by the Institute for Applied Economic Research (Ipea). Due to their relevance, they provide information to specialists and encourage contributions.

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CONTENTS

ABSTRACT

This paper intends to discuss the road ahead for the Brazilian innovation policies. To do so, it provides an overview of the several new policies adopted in Brazil in the last decade to foster technology and innovaton. Based on a broad review of Brazilian literature on evaluation of innovation policies, the document also presents the main achievements and outcomes of these policies as well as those that we consider to be their main misunderstandings. Finally, a range of policy challenges that have arisen as a result of efforts to encourage innovation in the Brazilian economy, and also presents some recommendations for overcoming them.

Keywords: innovation policies; Brazil; evaluation.

1 INTRODUCTION

Achieving sustainable productivity growth has long been a major challenge for the Brazilian economy. There is, of course, a diverse range of factors behind the low productivity growth of the Brazilian economy. In addition to the country's relatively closed economy and complex business environment, important bottlenecks exist in Brazil's infrastructure, and system of general education that significantly contribute to this problem. Despite these underlying factors and their effects (low labor productivity and weak innovation efforts), the capacity to incorporate, adapt, and produce new technologies is the most important determinant of Brazil's productivity growth in the long run.

Over the last few years, the Brazilian government has been very active in implementing a broad range of new policies to foster innovation in the country. Despite these efforts, outcomes have been modest. The question is why? This paper explores some answers to this question and presents the policy challenges arising from the current situation. Our findings explore two main paths. First, we argue that there are systemic conditions – factors related to competition and the institutional environment – that reduce the Brazilian economy's capacity to innovate. Second, both the design and the implementation of Science, Technology and Innovation (ST&I) policies lack the necessary efficiency to transform scientific potential capacities into private innovation.

Through an input/output analysis, a historical perspective and a meta-analysis, this policy paper aims to present – for the first time – a complete overview of the current Brazilian innovation system. Because this paper represents the first comprehensive examination of Brazilian innovation policy, this is an exploratory and descriptive work rather than one that attempts to test a hypothesis; instead this study seeks to launch the basis on which new hypotheses may be elaborated.

The main hypotheses related to Brazil's low technology performance have already been tested in many recent works, specifically De Negri and Cavalcanti (2014); De Negri and Squeff (2015); Rauen (2017) and Turchi e Moras (2017). Also, many instruments and policies have already been evaluated; we will review each of them in a section examining their impacts.

The current problem is that there is no single work that seeks to extract a combined meaning and formulate a future line of action from these studies. In fact, this is a much-needed work since Brazil has, during the last ten years or so, implemented many different instruments and policies to foster innovation.

The creation an overview of this kind has made it possible to identify major policy constraints. Since this is a policy paper, a specific section has been dedicated to proposing a range of actions to overcome these constraints.

It can certainly be said that Brazil has a diversified set of innovation policies and programs, from tax incentives and low-cost lines of credit to grants for firms and researchers. Brazil has also adopted a number of regulatory measures, as well as a few demand-side innovation policies (DSIPs).

In order to collect and organize data connected to these policies, it was necessary to rely on several different sources of information since no single government institution is currently able to present a general picture of these instruments. Therefore, this work has been produced through extensive use of several datasets that focus primarily on innovation policies and evaluation studies published by high-level institutions and journals.

To achieve its objective, this paper is divided into three sections, beside this introduction. The next section presents the main innovation policies adopted in Brazil in the last ten years or so. Section three focuses on what we know about the results and outcomes of these policies. The concluding section presents a range of policy challenges that have arisen as a result of efforts to encourage innovation in the Brazilian economy, and also presents some recommendations for overcoming them.

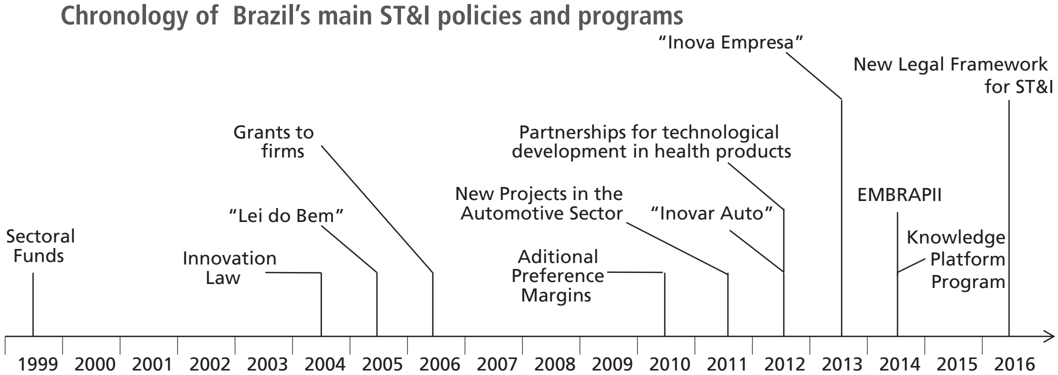
2 A BRIEF OVERVIEW OF BRAZIL'S INNOVATION POLICIES

Over the last decade or so, Brazil has implemented several new measures and policies to foster technology and innovation (figure 1). The aim of this section is to provide an overview of these policies, or at least the most relevant ones. It is important to notice that this work is not concerned with the range of industrial policies adopted by the country during the same period. The reason behind this is simple. Most of the industrial policies adopted had objectives other than innovation; in other words, these policies were geared towards increasing local production, exports, investment, and employment, or even leveraging aggregate demand in periods of low growth. The policies and programs presented in this section are those aimed explicitly at fostering innovation in the country.

With respect to the period of analysis (the last ten years or so), the first breakthrough in Brazilian innovation policy was the creation of the so-called Sectoral Funds. These funds were created in 1999 using taxes and contributions from different economic sectors, such as oil and gas, telecommunications, energy, and so on, with each of the sectoral funds having its own specific source of funding. These sectoral funding sources were complemented with other sources, such as a specific tax on foreign technology acquisition known as *CIDE-tecnologia*, which levies any technological contract (e.g., those related to technical assistance, licensing, and so on) in which Brazilian companies acquire technology from non-residents.[1]

Today, the Sectoral Funds are straining to fulfill the goals they were created to achieve as a result of two main government decisions: *i*) changes in the destination of royalties from oil companies (these resources are now being applied to health and education) and *ii*) a heavy fiscal blockade by the federal government on the collected resources of these funds.

FIGURE 1
Chronology of Brazil's main ST&I policies and programs



Elaborated by the authors.

1. Of course, the side effect of this tax is that it increases the cost of acquisition of foreign technology by 10% (the tax aliquot).

The Sectoral Funds are explicitly intended to promote business investments in innovation through partnerships between universities and research institutions on one hand and industry on the other. The funds are also aimed at providing an expanded and more stable source of funding for scientific and technological development since the general understand that the recurrent fiscal crisis in the country was eroding the budget for S&T (see, for instance, Pacheco, 2007).

Together with resources from the National Treasury and interests from innovation loans, the Sectoral Funds form the National Fund for Scientific and Technological Development (FNDCT), which was created in 1969 but refreshed in 1999 with funding from sectorial sources.

Another important improvement in the Brazilian innovation ecosystem was the implementation of the Innovation Law (Law nº 10,973/04) in 2004, which stipulates the rules for researchers from public institutions participating in research projects with companies and the guidelines for the commercialization of intellectual property rights derived from these partnerships. Indeed, this law was intended to stimulate the sharing of facilities as well as human and financial resources between the public and private sectors. Beyond this, one of the most important aspects of the law was that it created the possibility for the State to subsidize R&D investments at private companies through grants, something that had not been possible within Brazil's legal framework up until that point.

A more modern scheme of tax incentives to encourage companies to invest in R&D was put in place in 2005, when the so-called "*Lei do Bem*" (Law nº 11,196/05) was enacted. The *Lei do Bem* represented a significant improvement for business strategy since it established a specific tax deduction that could be automatically applied to R&D investments. Both the Innovation Law and the Lei do Bem were implemented during the first term of President Lula's government in the context of the new industrial policy (Industrial, Technological and Foreign Trade Policy – PITCE) launched in 2003. This policy could be described as a horizontal policy, something very different from later industrial policies adopted by the country. Up until that point, there were three schemes of tax incentives related to innovation in Brazil: *i*) Informatics Law; *ii*) ST&I deduction for firms; and *iii*) PDTA/PDTI.

The most important of these schemes in terms of volume of money was the Informatics set of laws (Laws nº 8,248/1991, nº 10,176/2001 and nº 11,077/04) or simple Informatics Law. This law, however, was not primarily oriented towards fostering R&D in Brazil but was designed to increase the amount of local content in the electronic and informatics products produced in the country. To encourage the inclusion of local content, the law gives tax breaks on manufactured products if companies follow some basic rules (called "basic production processes," or PPPs according to the Portuguese acronym) in the production of eligible goods. Basically, the Brazilian government tells companies how they should produce specific goods using inputs and components sourced from the local market. If the company decides to invest in R&D, an additional tax reduction is granted.

The second scheme, the oldest tax break in Brazil related to ST&I, was established in Law nº 4,506/64 and permits tax deductions from a firm's annual income tax. While it doesn't have the same volume as the Informatics' Law, it is still quite relevant. In this tax reduction, ST&I investments can be declared as operating expenses and not as inputs in the production process (the result is a lower taxable profit).

Finally, the third scheme of tax breaks for innovation, which existed in Brazil up until 2005, consisted of the Agriculture Development Program (Programa de Desenvolvimento Tecnológico Agropecuário or PDTA) and the Industrial Development Program (Programa de Desenvolvimento Tecnológico Industrial or PDTI). Both programs were created in the early nineties and aimed at granting tax breaks to firms investing in R&D. However, in order to qualify for a tax reduction, companies had to present research proposals to the Ministry of Science and Technology. The bureaucracy involved in applying for this incentive resulted in only 100 companies benefitting from this tax break during the last decade.

After 2005, many other tax breaks were created with the explicit objective of spurring innovation, among them the "Inovar Auto" Program (Law nº 7,819/12) stands out. This is the current automotive industry regime and this incentive was designed not only to support innovation, but also to guarantee employment and production. In the context of this regime, the tax incentive program for new projects in automotive industries in peripheral regions of the country (Law nº 12,407/11) is also siginficant.

There are also tax incentives for innovation in defense (the Special Tax Regime for the Defense Industry, the Regime Especial Tributário para a Indústria de Defesa or RETID) and the aerospace industry (the Special Regime of Tax Incentives in Aerospace Industry, the Regime Especial para a Indústria Aeronáutica Brasileira or RETAERO) and other older tax incentives for scientific research such as the machinery and equipment importation incentives offered by the National Council for Scientific and Technological Development (CNPq).[2]

In terms of demand-side innovation policies, the main initiative was the 2010 launch of a type of "Buy Brazilian Act" that allowed a preference margin of up to 25% to local producers if the product or service they supplied was not only produced in Brazil but developed domestically as well. Local suppliers of products that were not domestically developed had fewer margins, depending on the economic sector (Law nº 12,349/10).

Another demand-side innovation policy initiative was the program known as Partnerships for Technological Development in Health Products, which linked long-term government procurement contracts with the total transfer of the technology involved in the development of specific products (see for instance, VARRICHIO, 2017).

Within the scope of the Greater Brazil Plan (launched in 2010), FINEP and the Brazilian National Development Bank (BNDES) launched the Innovate Company Program in 2013. This was a massive public line of credit with subsidized interest, which focused on innovation projects rather than just R&D.

In 2014, the federal government launched two bold initiatives: i) the Knowledge Platform Program and ii) the Brazilian Industrial Innovation and Research Corporation (Empresa Brasileira de Pesquisa e Inovação Industrial, EMBRAPII).

The first of these was an ambitious program designed to overcome societal problems through technology procurement. In fact, this was the first time Brazil had attempted a more mission-oriented R&D approach. Unfortunately, the political turmoil that took place just after the launch of the program prevented its implementation.

2. Laws no 12,598/12; no 12,249/10 and no 8,010/90, respectively.

In contrast, EMBRAPII is currently fully functional and growing. EMBRAPII is a public funding agency inspired by the German *Fraunhofer* model and is aimed at fostering innovation projects in partnership with private companies. The agency works with accredited research institutions authorized to operate under the quality rules of the agency. Although there has yet to be a formal evaluation of its results, the creation of EMBRAPII seems to have been an important institutional innovation in the Brazilian scenario. In fact, the first data available indicate a high level of R&D investment leveraging.

Summing up, all of the efforts that have gone into designing new policies have resulted in a relatively comprehensive framework of innovation policies and instruments. Currently, Brazil can rely on many of the same instruments used in most of the developed world, including *i*) subsidized credit for innovation; *ii*) tax incentives for companies to invest in R&D; *iii*) grants for companies to invest in R&D projects; *iv*) grants for research projects at universities and research institutions; and *v*) public investment through venture capital, etc.

In addition to the incentives for innovation offered in many developed countries, Brazil also has an unusual instrument to spur innovation in regulated sectors – obligatory R&D. By law, concessionary firms involved in energy and oil extraction must not only contribute to the above-mentioned Sectorial Funds, but also – through a federal approval process – invest in their own R&D projects. The consequence is a high level of external R&D investment that fuels the university system.

The total amount of money related to these policies is shown in Table 1 (first published in Zuniga *et al.*, 2016, and updated here). This table presents the main sources of the financial resources available to support innovation and R&D in the country. Some of the resources shown here are not strictly public and some are not budgetary resources. The figures shown in the credit policies row, for example, express the total disbursement of credit for innovation at BNDES and FINEP, and not the fiscal cost associated with the equalization of interest rates in these programs. In the same way, the resources associated with mandatory investments in R&D in regulated sectors express the total amount of obligatory R&D investment assumed by regulated companies and are, therefore, private resources that must be allocated to R&D by law. (Zuniga *et al.*, 2016). Therefore, any aggregation must be conducted carefully.

TABLE 1
Main ST&I policies and instruments in Brazil (2015)

Innovation and S&T policies and instruments (main sources of funding for S&T in Brazil)		Current Reais	US$ ppp
Tax breaks[1]	Informatics Law (Laws nº 8.248/1991, nº 10.176/2001 and nº 11.077/04)	5,022,390,000	2,716,273,661
	Business RD&I expenditures (Law nº 11,196/2005)	1,835,212,176	992,543,091
	Business S&T expenditures (Law nº 4.506/64 and Decree no 756/69)	1,323,754,218	715,929,810
	RD&I in automotive sector (Law nº 12.715/12, Decree nº 7.819/12 and Law nº 12,407/11)	2,850,284,180	1,541,527,409
	Other tax breaks[2]	877,032,545	474,328,039
	Total (tax breaks)	**11,908,673,120**	**6,440,602,011**
Subsidized credit for innovation	Disbursements by FINEP	2,603,000,000	1,407,787,994
	Disbursements by BNDES[3]	4,501,000,000	2,434,288,805
	Total	**7,104,000,000**	**3,842,076,798**
S&T public investment (excluding graduate studies expenditures)[4]	Federal investments	22,809,042,668	12,335,880,296
	State investments	8,974,188,001	4,853,535,966
	Total	**32,783,230,671**	**17,189,416,262**
Counterpart in R&D by companies in regulated sectors (private compulsory investment)	Electricity Regulatory Agency (ANEEL) R&D program[5]	392,460,000	212,255,273
	The National Petroleum Agency (ANP) R&D program	1,030,956,397	557,575,120
	Total	**1,423,416,397**	**769,830,393**

Source: Adapted and updated from Zuniga (2016) based on data from the Ministry of Science, Technology, Innovations and Communication (MCTIC); National Bank for Social Economic Development (BNDES); Brazilian Innovation Agency (FINEP); National Petroleum Agency (ANP); Brazilian IRS (Receita Federal do Brasi - RFB) and Koeler, Viotti and Rauen (2016).
Exchange rate=1.849.
Notes: [1] Estimates by the Brazilian IRS.
[2] Non-profit scientific organizations; machinery and equipment from the National Council for Scientific and Technological Development (CNPq); Support Program for Technological Development of the Semiconductor Industry (PADIS); Support Program for the Technological Development of the Digital TV Equipment Industry (PATVD), scientific research (Additional to Freight for Renewal of the Merchant Marine), and information and communication technology. It was not possible to estimate the tax breaks related to innovation in the Special Tax Regime for the Defense Industry (RETID) for the year 2015. The Special Regime of Tax Incentives for innovation in the Brazilian Aerospace Industry (RETAERO) was not available.
[3] Excluding the amount transferred to FINEP but including disbursements in the form of capital assets investment.
[4] Excluding the amount in the form of credit.
[5] 2012 data according to CGEE (2015).

Taking into account all federal and state government investments in addition to the public tax waiver and compulsory R&D, the government sector infused (directly and indirectly) more than R$ 52.2 billion (around US$ 28.2 bi) in ST&I in 2015. It is important to mention that not all R&D investments from Petrobras are included in these figures, although the private compulsory investment controlled by the National Oil Agency (ANP) includes Petrobras' contribution.[3]

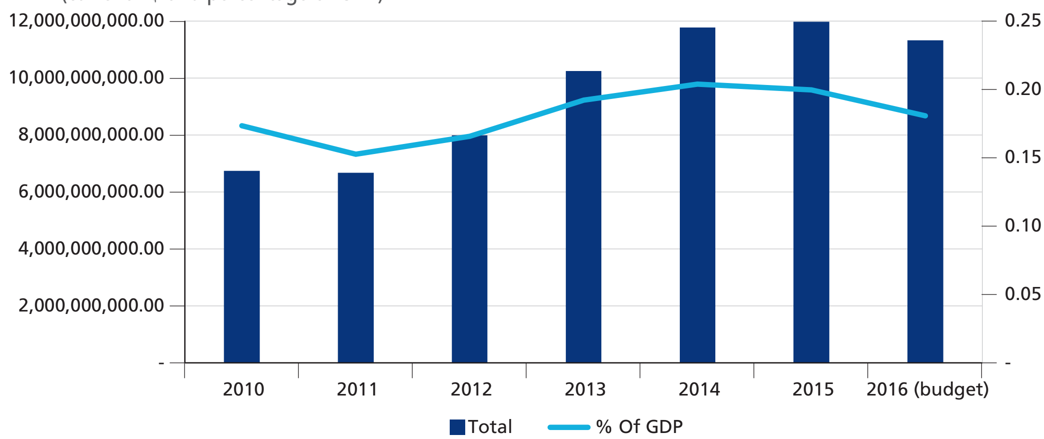
3. Indeed, the company's reports say that Petrobras invested US$2 billion in R&D in 2015, an amount greater than required to under the regulations of the National Oil Agency.

Table 1 encapsulates the big picture of innovation incentives in Brazil, outlining the most important innovation policies and investments in the country. The following subsections will address each and provide information about their evolution over the last few years.

2.1 Tax breaks for ST&I

The estimate total tax breaks for ST&I in Brazil in 2016 is close to R$ 11.3 billion. In Figure 2 there is a representation of the evolution of tax breaks for ST&I in Brazil since 2010 and the amount each represents in terms of GDP. According to the most recent estimates, fiscal incentives for R&D represented 0.18 percent of the Brazilian GDP in 2016 or US$ 5.7 billion (ppp).

FIGURE 2
Total tax breaks for ST&I in Brazil (2010-2016)
(current R$ and percentage of GDP)



Source: RFB.
Informatics Law; Business RD&I expenditures; RD&I in the automotive sector; Non-profit scientific organizations; machinery and equipment from the National Council for Scientific and Technological Development (CNPq); Support Program for Technological Development of the Semiconductor Industry (PADIS); Support Program for the Technological Development of the Digital TV Equipment Industry (PATVD), scientific research (Additional to Freight for Renewal of the Merchant Marine), and information and communication technology.
It was not possible to estimate the tax breaks related to innovation either for the Special Tax Regime for the Defense Industry (RETID) or for the Special Regime of Tax Incentives for the Brazilian Aerospace Industry (RETAERO).

The detailed analysis of the majority of Brazilian tax incentives for innovation shows that the country has many types of incentives beyond waivers. In fact, Brazil has a hybrid tax incentive scheme with both tax credits (i.e., *Inovar Auto*) and tax allowances (i.e., *Lei do Bem*).

As stated earlier, the most important tax exemption is provided to companies in the ICT sector (see table 1, figure 2 and table 2):

> This incentive was created by the Informatics Law (*Lei de informática*) in 1991 and was later reformulated, first in 2001 and then again in 2004 (Laws nº 8,248/1991, no 10,176/2001 and nº 11.077/04). These laws established some basic production and development requirements that must be fulfilled by firms in order to receive the tax deduction (Zuninga *et al.*, 2016: 64).

In terms of volume, the second most relevant tax break is related to the *Inovar Auto* Program (Law nº 12,715/12 and Decree nº 7,819/12) and to the policy promoting new automotive projects in peripheral regions (Law no 12,407/11).[4] The Innovar Auto Program allows fiscal deductions for three different types of investments: R&D investments, engineering investments, and investments related to energy efficiency. The policy promoting automotive projects in peripheral regions is a relatively unknown policy designed to support new developments in the auto industry outside the southwestern region of the country.

In third place is the *Lei do Bem* (Law no 11,196/2005). According to Rocha (2015) *apud* Zuninga *et al.* (2016:64):

> […] this law was enacted to reinforce changes in the Brazilian innovation system that started with the Innovation Law. In 2007, the tax incentives were updated through Law n° 11,487/07, which became known as the "Fiscal Incentives Law"; this legislation accelerated and expanded incentives for investments in innovative activities.
>
> The special tax regime and fiscal incentives for companies created by the Fiscal Incentives Law stipulate, among others: i) deductions from income tax and social contributions on net profits from expenses related to R&D (between 60 percent and 100 percent); ii) deduction in the tax on industrial products for purchasing machines and equipment for R&D (50 percent); iii) economic subsidies through scholarships for researchers in companies, and iv) an exemption from the Contribution for Intervention in the Economic Domain (*CIDE*) for patent deposits. It also includes funding for firms who hire employees with master's and doctoral degrees. The subsidy can provide up to 60 percent of an employee's salary in the north, northeast and Amazon regions and 40 percent in the rest of the country for up to three years (Rocha, 2015).

4. The *Inovar Auto* Program will end in December 2017. A new automotive program the "Rota 2030," is currently under discussion but has not yet been precisely defined.

TABLE 2
Fiscal incentives for ST&I in Brazil (2013-2016)
(Current R$)

Year	2013	2014	2015	2016Budget Bill
Informatics Law (Laws nº 8.248/1991, nº 10.176/2001 and nº 11.077/04)	4,934,898,642	5,207,255,217	5,022,390,000	5,306,577,826
Business RD&I expenditures (Law nº 11,196/2005)	1,636,850,880	1,749,177,703	1,835,212,176	1,981,829,983
Business S&T expenditures (Law n° 4.506/64 and Decree no 756/69)	1,180,623,055	1,261,673,268	1,323,754,218	1,428,692,397
RD&I in automotive sector (Law n° 12.715/12, Decree no 7.819/12 and Law n° 12,407/11)	1,791,230,535	2,643,496,344	2,850,284,181	1,604,267,495
Other tax breaks[1]	697,186,358	855,822,304	877,032,545	990,038,749
Total	**10,240,789,470**	**11,717,424,836**	**11,908,673,119**	**11,311,406,450**

Source: RFB.
Note: [1] Non-profit scientific organizations; machinery and equipment from the National Council for Scientific and Technological Development (CNPq); Support Program for Technological Development of the Semiconductor Industry (PADIS); Support Program for the Technological Development of the Digital TV Equipment Industry (PATVD), scientific research (Additional to Freight for Renewal of the Merchant Marine), and information and communication technology.

It was not possible to estimate the tax breaks related to innovation in the Special Tax Regime for the Defense Industry (RETID) or for the Special Regime of Tax Incentives for the Brazilian Aerospace Industry (RETAERO).

Law nº 4.506/64 regulates Brazilian Income Tax and permits deductions from the total income tax firms owe by allowing them to declare science, technology and innovation investments as operating expenses. Although academics and innovation policy specialists generally lack of knowledge of this instrument, it has been extensively used in recent years, according to the estimates of the Brazilian IRS (table 2).

Besides these, Brazil has also a range of minor tax break initiatives. Among these, the most prominent is the import tax reduction for R&D equipment and inputs used mainly by universities and non-profit research institutions; there are also a number of incentives for the implementation of digital TV and for the semiconductor industry.

Considering the data shown in Table 1 and the fact that most of the official government expenditures in S&T are directed towards public institutions, like universities and research centers, the fiscal incentives shown here are the main instruments used to support innovation in firms. Subsidized credit is the second most widely used instrument.

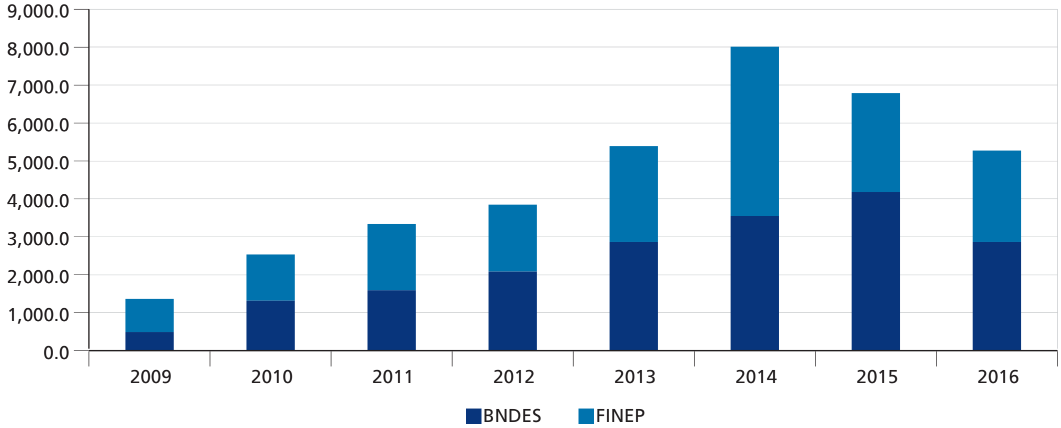
2.2 Subsidized credit for innovation

Prior to 2014 the subsidized credit for innovation was experimented the highest budgetary expansion. This type of instrument is used by the BNDES and FINEP (figure 3). In fact, as already presented in ZUNIGA *et al*. (2016), "FINEP, the main innovation agency, has seen its budget for subsidized credit increase more than ten times since 2007".[5]

> Until 2010, the largest portion of FINEP's budget went to the FNDCT (R$1.1 billion), which targeted research infrastructure and academic research, mainly in universities. Since 2010, however, the budget for credit has increased sharply, having benefited from the Investment Maintenance Program (PSI) launched after the international financial crisis of 2008. The increase due to the PSI raised the share of credit in FINEP's budget to more than 80 percent in 2014 (ZUNIGA *et al*., 2016).

However, changes in FNDCT's constitution and strong fiscal constraints in Brazil caused the allocation of resources to FINEP to plummeted in 2015 and 2016. In fact, there has been a strong reversal in FINEP's disbursements series since 2014 (figure 3).

FIGURE 3
Disbursements of credit for innovation in Brazil, by agency (2009-2015)
(Current R$ billion)

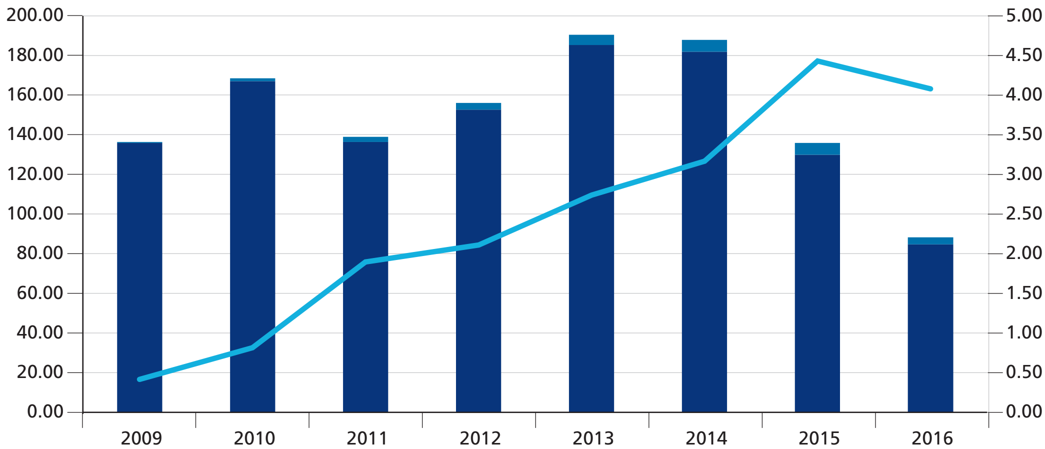


Sources: BNDES and FINEP.
BNDES values exclude the amount transferred to FINEP and disbursements in the form of capital asset investments.

5. FINEP is also responsible for the implementation of part (not all) of the resources allocated by the FNDCT. The next section analyses FNDCT.

The credit to innovation in BNDES that was around R$0.6 billion in 2009 grown to about R$4 billion in 2015. Even so, innovation only represents a small amount of BNDES' total portfolio, which reached disbursements of R$88.3 billion in 2016 (figure 4).

FIGURE 4
Innovation investment in total BNDES disbursements
(Current R$ billion and % of total)



Source: BNDES.

A portion of FINEP's credit budget comes from BNDES through the PSI Program. Therefore, considering the amount that BNDES has transferred to FINEP, the total disbursements for innovation contributed by BNDES reached R$6 billion in 2015 and 3.6 billion in 2016 (around 4.4 and 4 percent of total BNDES disbursements, respectively).

The important message here is that credit for innovation has only recently become widely available, but the growth of this mechanism was quickly replaced by a downward trend.

2.3 Official S&T public expenditure

The Brazilian public sector (federal and state governments combined) spent approximately R$33 billion on science and technology in 2015, as shown in Table 1. These figures do not represent the total S&T public investment in Brazil, since close to 36% of the investment designed to maintain university graduate courses and institutions (at both the federal and state levels) is not included in these figures.

TABLE 3
Federal S&T investments in Brazil in 2015 (excluding graduate studies investments)

Ministries	R$ Million	%
Total Federal Budget To S&T	24,675.7	100
Ministry of Education (MEC) – mainly CAPES	8,103.1	32.8
Ministry of Science, Technology and Innovation (MCTI)	7,246.7	29.4
Ministry of Agriculture (MAPA) – mainly EMBRAPA	3,135.5	12.7
Ministry of Health (MS) – mainly FIOCRUZ	2,273.7	9.2
Ministry of Development, Industry and Foreign Trade (INMETRO and INPI)	1,042.4	4.2
Ministry of Planning (IBGE)	1,237.1	5.0
Others	1,637.1	6.6
Ministry Of Science, Technology, And Innovation – Detailed Breakdown		
MCTI – TOTAL	7,246.7	100
FNDCT1 (Sectoral Funds)	2,803.4	38.7
National Counsel of Technological and Scientific Development (CNPq)	1,914.0	26.4
Headquarters and MCTI research institutions	1,757.0	24.2
Space program (Brazilian Space Agency - AEB)	220.7	3.0
Nuclear program (National Nuclear Energy Commission - CNEN)	551.6	7.6

Source: Estimates from Ipea (SIOP with guidance from the Frascati Manual).
Note: [1] Considering the credit under FNDCT.

In 2015, the public federal S&T investment (excluding graduate studies investments) reached R$24.6 billion (or around US$ 13.2 in ppp) with the largest shares allocated to the Ministry of Education (MEC) and the Ministry of Science, Technology and Innovation (MCTI) (table 3).

Table 3 presents a breakdown of these federal investments. The first consideration, already pointed at ZUNIGA *et al.* (2016) is that Brazilian S&T investments are not "mission-oriented," in the sense that most of these investments are not linked to ministries with a specific sectorial mission (foster infrastructures, health, education and so on), as is the case in other countries (see Mowery 2009). The two ministries responsible for the majority of S&T investments in Brazil are the Ministry of Education (MEC) and the Ministry of Science, Technology, and Innovation (MCTI), which handle more than 62% of the total investment:

> The main agency responsible for the MEC's investment in S&T is the Coordination for the Improvement of Undergraduate Education Personnel (CAPES); this means that most of its bud-

> get is attached to funding undergraduate and graduate scholarships at Brazilian and foreign universities. A recent program called Science without Borders (*Ciência sem Fronteiras* - CsF) is included in this budget (and also in the CNPq budget). The program, created in 2011, is aimed at promoting internationalization of Brazilian science and technology through the international mobility of students (ZUNIGA *et al.*, 2016:72).

Since 2011, more than 90 thousand students benefited from the program. But recent changes made by the Federal Administration virtually ended the program.

The Ministry of Agriculture (MAPA) invested around R$ 3.1 billion in S&T in 2015, which is about 13% of the total federal S&T investment.

> The main agency responsible for almost all of MAPA's investments in S&T is the Brazilian Agricultural Research Corporation (EMBRAPA); this agency is also considered a Brazilian success story in terms of technology and innovation. One of the reasons for EMBRAPA's success is that it is a highly specialized, mission-oriented research institution. In fact, EMBRAPA is responsible for several developments like, soybean cultivation in the dry and hot climate in central Brazil. Together with a number of other state research institutions, EMBRAPA is the center of the highly regarded National System of Research in agriculture.
>
> Another important mission-oriented research institution in the Brazilian innovation system is the Oswaldo Cruz Foundation (FIOCRUZ), which is under the supervision of the Ministry of Health. Almost all of the ministry's S&T budget is attached to FIOCRUZ. This institution has a broad scope, and it focuses on education and basic and applied research, particularly in public health and related areas.
>
> In the Ministry of Industry, the S&T budget is allocated to the Brazilian Patents Office (INPI) and to the National Institute of Metrology, Quality, and Technology (INMETRO). Finally, in the Ministry of Planning, the Brazilian Institute of Statistics (IBGE) handles most of the ministry's S&T budget (ZUNIGA *et al.*, 2016:73).

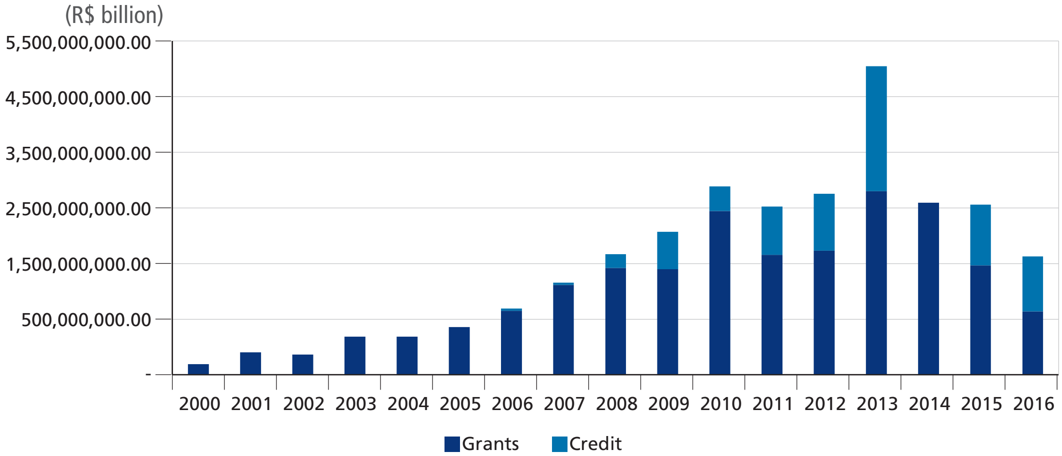
Historically, MCTI was the main source of S&T funding, and for this reason we focus on an analysis of this agency. In fact, 2015 is the first time MEC surpassed MCTI in terms of volume. The reasons for this new phenomenon are associated with the decrease in the FNDCT – the main source of funds for MCTI – and the execution of CsF Program by MEC. Furthermore, MCTI is the agency that is primarily responsible for the ST&I strategy in Brazil, and for this reason, it is relevant to examine the Ministry's spending in detail.

FNDCT is the most important source of funding for S&T in the country. From 1999 onwards, the Sectorial Funds began to fund FNCDT, as previously mentioned. Figure 5 shows the evolution of FNDCT's budget execution from 2000 until 2016:

> The FNDCT supported a broad range of actions by the Brazilian Government to foster innovation. Most of the budget is composed of grants to universities and research institutions, some of which are in partnership with firms (ZUNIGA *et al.*, 2016:73).

FNDCT also funds grants to firms for the development of R&D projects, in addition to equalization of the interest rates charged by FINEP for loans awarded to innovation projects and direct investment in innovative companies through venture capital and seed money funds.

FIGURE 5
FNDCT's total budget execution (2000-2016)
(R$ billion)

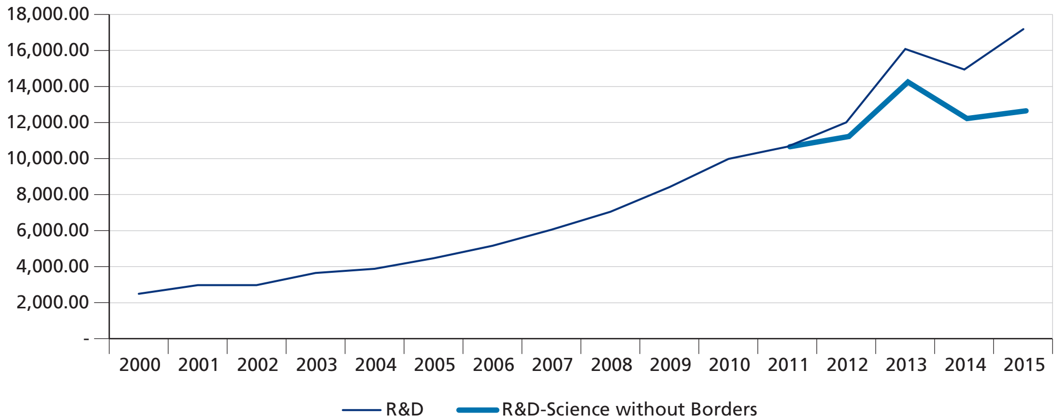


Source: SIOP

Looking specifically at research and development (R&D) expenditures, which are the main component of S&T expenditures, Figure 6 shows high growth in the 2000-2015 period, but the results also show that this growth is directly linked to the CsF Program and its exchange rate correlation[6]. In fact, excluding the CsF Program (which was aimed at international undergraduate scholarships) the total R&D expenditure fell from 2013 to 2015.

6. In 2015, the dollar had an annual appreciation of 48% against the real.

FIGURE 6
R&D expenditures (excluding graduation studies investments) and R&D expenditures (excluding graduation studies investments) without CsF. Brazil (2000-2015)
(R$ billion)



Source: SIOP.

The CsF situation is a clear example of the way Brazil's official S&T investment (even without graduate studies investments) is primarily designed to support universities and research institutions rather than firms. In other words, the term R&D is more representative of scientific research activities than final development.

2.4 Compulsory R&D investments in regulated sectors

Another relevant policy in terms of volume is related to regulated sectors, such as electricity and oil and gas. In both sectors, companies operating in Brazil are required to invest a share of their turnover in R&D activities within the country. In other words, this is an obligatory R&D strategy.

In the case of the electricity sector, the Brazilian government requires that private electric utilities invest up to 1% of their net operating income (NOI) in R&D projects. To comply with the regulations, companies must submit research projects to the ANEEL for prior approval; otherwise they may be fined for failing to comply with their investment obligations.

In the same way, the National Petroleum Agency (ANP) requires oil companies in the more profitable oil fields to make R&D investments of up to 1% of their gross revenues. These investments must be made in universities or research institutions in Brazil. As is the case with the electricity agency, the oil agency must approve the company's R&D projects and, more recently, the ANP has also created an accreditation process for universities and research institutes to qualify to receive money from the program. The debate over the framing of corporate R&D projects according to agency regulation is a source of controversy. This is why a relevant share of Petrobras' investments in R&D is not recognized as R&D by the regulatory agency.

Despite these problems, as a result of the recent growth in oil production in the country, the private compulsory investment from ANEEL and ANP has been growing in the last few years (table 4).

TABLE 4
Private compulsory investment from ANEEL and ANP (2001-2015)
(R$ current)

Year	Agency	
	ANEEL	ANP
2001	90,000,000	127,274,445
2002	128,000,000	263,536,939
2003	148,000,000	323,299,906
2004	141,000,000	403,703,639
2005	163,000,000	508,808,454
2006	200,000,000	616,389,336
2007	282,000,000	616,503,267
2008	258,000,000	860,858,233
2009	270,000,000	638,882,284
2010	310,000,000	746,917,021
2011	332,000,000	1,031,896,895
2012	392,000,000	1,226,686,691
2013	n.a	1,259,866,957
2014	n.a	1,407,565,231
2015	n.a	1,030,956,397

Sources: CGEE (2015) and ANP.

Finally, the resources induced by the government (shown in table 1 and detailed above in table 3) are also applicable in the form of demand-side innovation policies (DSIPs), such as technology procurement and public procurement for innovation (PPI). For instance, this is true of Partnership for Technological Development in Health

Products. But as shown by Rauen (2017) these demand-side policies are marginal both in terms of value and number. In fact, this is one of the most important features of the current Brazilian innovation policy – it's heavy concentration on the supply side.

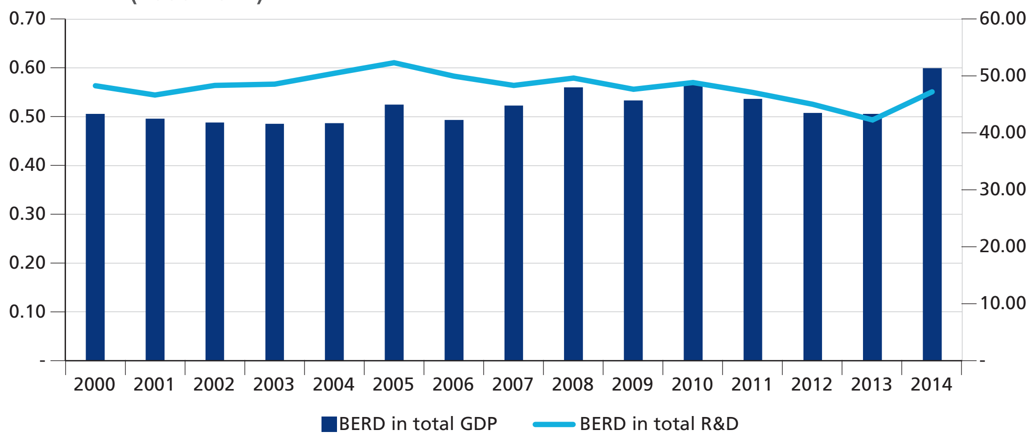
Following this survey of policy efforts, the next section presents an overview of their macro outputs in terms of their influence on private innovative behavior in Brazilian firms and the consequences for international competitiveness.

3 MACRO OUTPUTS

As already mentioned, not all of the resources presented here are executed to support private innovation. Many are designed to spur science and contribute to the public academic system. Yet, the ultimate intent of the S&T policy is to build better societies through socioeconomic development. In this way, the expectation is that these policies will change private behavior, encouraging firms to assume more risk and explore new technological possibilities. In other words, in capitalist societies, increased private investment is expected follow from increased S&T public investment.

In this sense, we can ask ourselves whether the policy efforts previously presented have transformed the private behavior of Brazilian firms regarding innovation. And, if so, are Brazilian firms now more competitive? These are the two main questions that guide this section.

FIGURE 7
BERD as a percentage of GDP (left axis) and as a percentage of total R&D (right axis). Brazil (2000-2014)

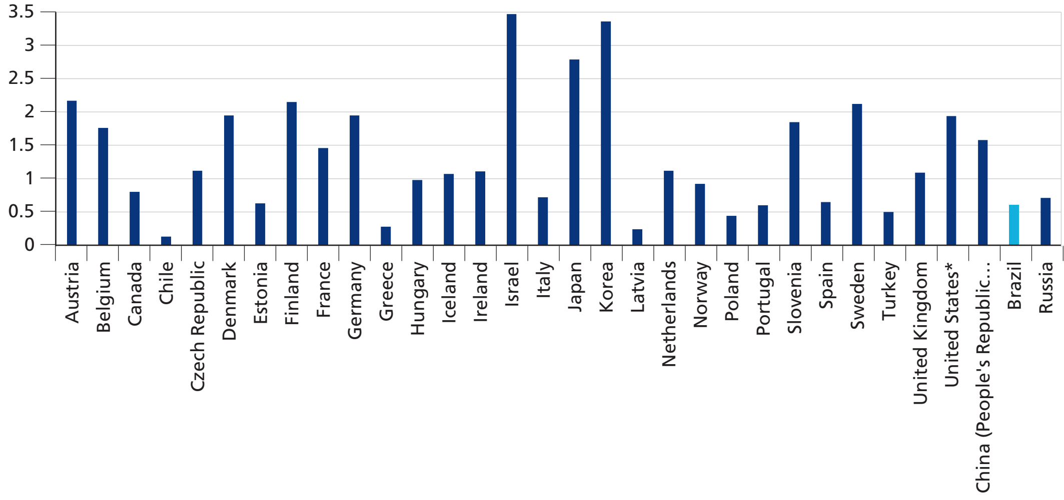


Source: MCTIC.

Despite the efforts of the last decade, Figure 7 shows that nothing has really changed in terms of the R&D structure and intensity of the Brazilian economy. In fact, business participation in R&D has decreased between 2000 and 2014. Business R&D intensity – which had been quite stable over the entire period – did increase slightly in 2014. However, this was due to the low growth of the Brazilian GDP and uncommon expenditures on external R&D by telecom service companies (possibly related to the FIFA World Cup and the Olympic Games). Therefore, in general, there seems to have been little or no change in private behavior with respect to R&D efforts.

Figure 8 shows that this stable pattern in BERD consolidates Brazil's peripheral position regarding R&D intensity on the international stage. The data presented in Figure 8 also helps to explain the international division of labor and the historical dependence on technology in the Brazilian economy.

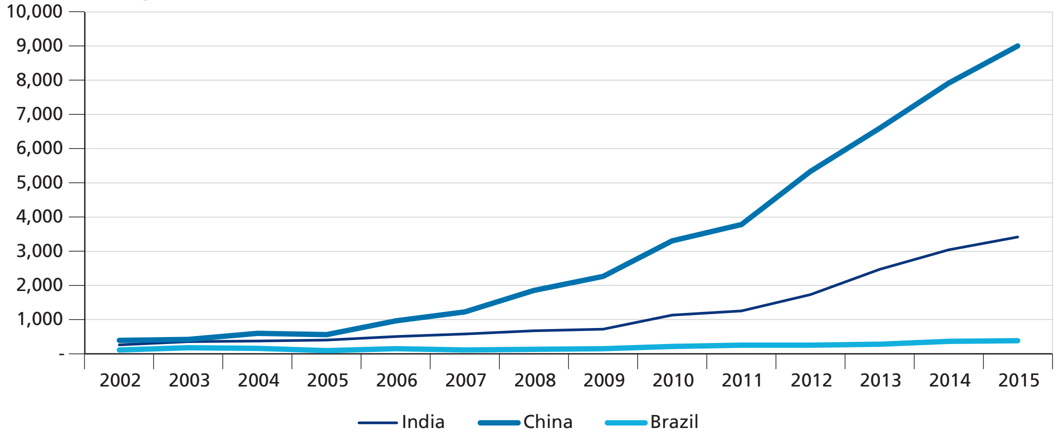
FIGURE 8
BERD as percentage of GPD, selected countries, 2014 or last year available



Source: MCTIC and OECDstat.

In the last 10 years and in terms of the total number of patents in the United States Patent Office (USPTO), the Brazilian situation is still unchanged. In other words, Brazil is still a peripheral country, even when compared to developing countries like India and particularly China (figure 9). Taking into account total R&D investment, each patent granted to a Brazilian firm or individual by the USPTO in 2015 cost, on average, US$ 109 million, which is much more than the Chinese cost of US$ 43 million per patent in 2014 and the Indian cost of US$ 37 million per patent in 2011 (MCTIC and OECDstat, ppp).

FIGURE 9
Patent grants at USPTO, selected countries (2002-2015)



Fonte: USPTO.

As a consequence, Brazil is losing ground in terms of international competition. For instance, in the 2007 *Global Innovation Index*, Brazil was the 40th most innovative country in the world. But in 2017 its position fell to 69th, well behind China, India, South Africa and Russia (Table 5).

TABLE 5
Global Innovation Index, selected countries (2007-2017)

Edition	**Brazil**	China	South Africa	Russia	India
2007	**40°**	29°	38°	54°	23°
2008	**50°**	37°	43°	68°	41°
2009	**68°**	43°	51°	64°	56°
2011	**47°**	29°	59°	56°	62°
2012	**58°**	34°	54°	51°	64°
2013	**64°**	35°	58°	62°	66°
2014	**61°**	29°	53°	49°	76°
2015	**70°**	29°	60°	48°	81°
2016	**69°**	25°	54°	43°	66°
2017	**69°**	22°	57°	45°	60°

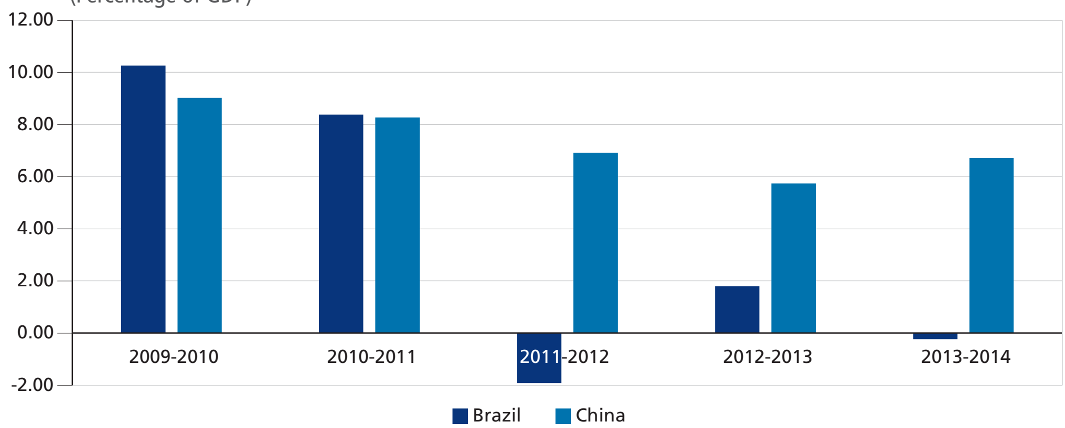
Source: CORNELL University.

As observed in many recent studies – including De Negri and Cavalcanti (2016), De Negri, Rauen and Squeff (2018) Rauen (2017) and Turchi and Moraes (2017) – this result is in part due to the lack of structural reforms that could potentially reduce the opportunity costs of innovation and improve the business environment in the country. In fact, according to *Doing Business* publication, Brazil is only the 123° country in the world in terms of conducting business (World Bank, 2017).

Figure 10 shows the end result of this scenario. Brazilian productivity is still higher than Chinese productivity, but the country is losing ground fast. In 2009, Chinese productivity was US$ 14.7 thousand per person engaged, and in 2014 it reached US$ 21.5 thousand, an increase of 32%. On the other hand, Brazilian productivity was US$ 26.5 thousand in 2010 and US$ 29 thousand in 2014, an increase of just 18%.

The most relevant macro output of innovation policies is the total labor productivity. As Figure 10 shows, in the last years the Brazilian labor productive fell.

FIGURE 10
Labor productivity annual growth, Brazil and China (2009-2014)
(Percentage of GDP)



Source: University of Groningen.
Number of persons engaged and output-side real GDP at chained PPPs (2011US$).

Brazilian productivity stops increasing and enters a period of stagnation. In fact, between the 2011-2012 and 2013-2014, Brazil's productivity decreased. China was on its way, despite a recent decline in the country's growth rate.

These are the macro outputs: a persistent low private R&D intensity, stagnation in private R&D participation, disproportional technology dependence, a hard business environment and very low productivity growth.

The next section will present the evidence that we have so far gathered to explain the specific influences that led to this situation.

4 WHAT WE KNOW SO FAR: A COLLECTION OF DIFFERENT STUDIES

Although a number of official documents state the relevance of impact assessments with regard to innovation policies in Brazil, there has been no real coordination of such activities. In fact, impact assessment in Brazil in general, beyond the examination of innovation policies, is one of the most fragile areas in the policy-making process. One of the main reasons for this gap is the absence of official data that are publicly available.

However, the efforts of academics and policy analysts in universities and think tanks have provided us with scattered evidence regarding the impact of several innovation policies. This section presents the evidence we have so far concerning the effectiveness of a number of the most important innovation policies in the country.

Relatively few of the policy instruments previously presented have been subjected to a proper evaluation process. Most of them, like credit for innovation and obligatory R&D, have yet to be assessed. In this section, we present and discuss all of the relevant studies we have found so far in our research.[7]

In terms of tax benefits for ST&I, Brazil has a very generous approach. There are more than a dozen laws related to a variety of different tax benefits schemes. Brazil offers a mixture of tax credits (i.e., Inovar Auto) and tax breaks (i.e., *Lei do Bem*) to private business. But, as shown by the OECD, Brazil's generosity is focused on its largest companies.[8]

The total amount of available tax breaks for ST&I in Brazil is about US$ 5.7 billion (2015), and tax breaks are the most relevant policy instrument in terms of

7. We conducted an Internet search of Google Academics, the websites of major Brazilian universities, federal accountability offices and the webpages presenting the policy instruments being studied.
8. Disponível em: <http://dx.doi.org/10.1787/888933619448>.

volume. But, this instrument is not focused solely on big firms and its use is high concentrated in only two sectors, ICT and automotive.

Of all tax incentive schemes, the most frequently evaluated are the Informatics Law and the *Lei do Bem*. Both are under the umbrella of the recently created Ministry of Science, Technology, Innovations, and Communications – MCTIC (which combines the MCTI and the Ministry of Communication).

First, let's consider one of the first tax incentives created in the country related to innovation, the Informatics Law. This law benefited more than 510 firms in 2014. Microdata from 2010 (the last year available for this kind of analysis) reveals that:

> […] more than 60 percent of firms benefitting from this incentive had less than 99 employees in that year. However, since the tax incentive focuses on the production tax (tax over industrialized products), the incentives are strongly correlated with the sales figures of firms. Therefore, most of the total value of tax exemptions was appropriated by the country's 45 largest companies (those with more than 500 employees) (ZUNIGA *et al.*, 2016:65).

TABLE 6
Total value of tax exemption provided by the Informatics Law in 2010 and number of beneficiary firms, by size

Size of firm	Tax exemption (R$)	Number of beneficiary firms
Less than 30 employees	40,995,961.74	108
30 to 99 employees	149,420,106.95	122
100 to 249 employees	238,641,019.78	65
250 to 499 employees	245,257,027.44	27
More then 500 employees	2,896,450,273.41	45
Total	**3,570,764,389.32**	**367**

Source: ZUNIGA *et al.* 2016.

Possibly because the law was created in the early 1990s, over the years there have been several different attempts to evaluate its results and impact. Table 7 shows the main recent ones, which allow us to question the legislation's effectiveness.

TABLE 7
Main studies on the Informatics Law

Author/year	Main objective	Method	Main finding
RIBEIRO, E.; PROCHNIK, V.; DENEGRI, J. (2011).	Impacts on the firm's productivity	Logit model based on input and output differentials	The program doesn't affect the participant's productivity.
SALLES FILHO *et al*. (2012).	Effects on productive and techno-logical density	Qualitative approach with in-depth interviews and secondary data	There are no effects on productive and technological density in the ICT national productive chain.
KANNEBLEY e PORTO (2012).	Impacts on R&D investment	Quasi-experiment	The evidence suggests that the program crowds out private R&D investment.
Prochnik *et al*. (2015)	Assessment of the political issues behind maintenance of the law	Political economy analyses	The primary reason behind the ICT law is to create some political bal-ance between firms in the tax-free zone of Zona Franca de Manaus and firms in the State of São Paulo.
SILVA, g. (2017)	Impacts on the firm's innovation and R&D efforts	Estimation with probit regressions for an unbalanced panel with random effects	There is a positive effect on all innovation strategies in the Brazilian ICT firms.

Elaborated by the authors.

With the exception of SILVA (2017), it is evident that all of the studies reviewed in this survey analyzing the effects of the Informatics Law on R&D or on the productivity outcomes of the beneficiary companies show either no impact or a negative impact.

> According to Salles *et al*., the 2012 law reinforces the problems already identified in previous studies: low international competitiveness of beneficiary firms, low value added as a share of total Brazilian production, and low scientific density of the investments made in the country (ZUNIGA *et al*., 2016:66).

Kannebley and Porto (2012) shows that the law has proven to be ineffective in stimulating R&D in Brazilian companies and has failed to foster international competitiveness. Finally, Prochnik *et al*. (2015) reveals the political economy behind the Informatics Law shows that it was designed to compensate companies in the Manaus Free Trade Zone.

However, a more recent study by Silva (2017) shows some positive impacts in terms of innovation strategies and market competition. But it is important to point out that this study didn't test the ICT Law additionality. In fact, the evidence we have so far indicated a crowding out effect.

The *Lei do Bem*, seems to be quite different in terms of impact. Soon after the implementation, the law was criticized for not allowing small businesses to benefit from taxes deductions and for having few beneficiary companies.

> In fact, in 2006, only 130 firms benefited from this instrument. These firms received around R$200 million in tax exemptions and invested around R$2.2 billion in R&D (Zuniga *et al.*, 2016:66).

The number of beneficiary firms grew to 991 firms in 2014, which were investing more than R$8 billion in R&D (around 24% of the total BERD) and receiving R$1.7 billion in tax exemptions. In total, 5,589 firms have benefited from the *Lei do Bem* from 2006 to 2014 (Table 8).

TABLE 8
Total value of tax exemption provided by *Lei do Bem*, number of beneficiaries and R&D investments of beneficiaries, by year

Year	Number of beneficiaries	Tax exemption (R$ bi)	R&D investment (R$ bi)	Exemption from R&D
2006	130	0.23	2.19	10.5%
2007	300	0.88	5.13	17.2%
2008	460	1.58	8.80	18.0%
2009	542	1.38	8.33	16.6%
2010	639	1.70	7.10	23.9%
2011	767	1.40	6.84	20.5%
2012	787	1.04	5.34	19.5%
2013	973	1.58	6.73	23.5%
2014	991	1.68	8.07	20.8%

Sources: MCTIC (2017).

Regarding its impacts, the studies shown in Table 9 suggest that the *Lei do Bem* had additionality effects over private R&D investments until 2009/2010. In fact, these studies reject the hypothesis of crowding out and suggest the existence of an additionality effect related to the tax breaks (e.g., Shimada, Kannebley and De Negri, 2014). However, a new study by Zucoloto *et al.* (2017) showed a crowding out effect possibly associated with the growing number of beneficiaries. However, this study also showed that the tax incentive had a high impact on the productivity of the firms. In other words, the law is quite relevant but requires improvements to enhance its efficiency.

TABLE 9
Main studies on the *Lei do Bem*

Author/year	Main objective	Method	Main findings
ARAÚJO *et al*. (2010)	Marginal costs of R&D after tax breaks	Descriptive statistics	Favorable tax environment for R&D investments. Brazil is among the most generous countries in terms of tax breaks for innovation.
KANNEBLEY JÚNIOR and PORTO (2012)	Impact on R&D investments of beneficiary companies	Quasi-experiment	The participation in the program increases the private R&D investments 7% to 11%. Additionality effect.
SHIMADA, KANNEBLEY JÚNIOR and DE NEGRI (2014)	Impact on R&D investments and R&D personnel	Panel data	Large increase in private R&D investment and in the number of technical personnel
PORTO *et al*. (2014)	Qualitative – direct and indirect – effects of the program	Qualitative approach within-depth interviews and secondary data	Regular and stable financial availability that helps the firms to maintain R&D project in phases of the economic crisis.
ZUCOLOTO *et al*. (2017)	Impacts on R&D investments and firm productivity	Quasi-experiment with the elasticity of PTF	There is an increase in R&D investment of proximally 17%, but with a crowding out effect. There are positive effects on firms' productivity.

Source: Authors.

As previously stated at Zuniga *et al*. (2016:67):

Some insights into the role of R&D tax incentives for innovation can also be gathered from international evidence (OECD, 2015). Such work shows, for example, that the benefits of R&D tax support may be skewed. In particular, large, incumbent and multinational firms may be best placed to reap the benefits from such measures. This is due in part to their capacity to exploit international tax-shifting opportunities. It may also be due to the design of the tax incentives themselves. For instance, if there are no carry-forward provisions, new firms may not be able to benefit. But this doesn't mean that small companies can't also benefit from the instrument.

Bravo-Biosca, Criscuolo, and Menon (2013) provide evidence of the impact of R&D tax subsidies on the distribution of employment growth in R&D-intensive sectors. This work shows that support for R&D only has a positive impact on employment growth in incumbent firms with relatively low growth rates, while it has a negative effect on firm entry and on the employment of firms at the top of the growth distribution. These results suggest that R&D tax incentives might favor incumbent firms and slow down the reallocation process. The effect of incentive design on overall firm dynamism is, therefore, of great importance.

It is therefore important that R&D tax incentives are refundable or contain carry-over provisions so as to avoid overly favoring less dynamic incumbents at the expense of dynamic young firms. The implicit subsidy rate of R&D tax incentives increases with the profitability of the firm and many young innovative firms are typically in a loss position in the early years of an R&D project. Thus, these firms will not benefit from the program unless it contains provisions for immediate cash refunds for R&D expenditure or allows such firms to carry associated losses forward to deduct against future tax burdens.

For the reasons outlined above, grants and other forms of direct support may be valuable as a complementary form of support for R&D, perhaps targeting the firms that are unlikely to benefit as much from tax incentives (e.g. young firms). In other cases it may be necessary to provide direct forms of support for more mission-oriented innovation projects that have elements of strong public good (e.g., public health, climate change, and national security). However, in such cases, the award selection process must be designed so as to ensure efficiency, avoid rent-seeking activities and avoid problems of adverse selection.

Tax incentives are the main policy instrument that has been implemented in order to spur innovation in Brazil, but the direct public investment has also played a significant role. In this context, FNDCT is the most relevant source of ST&I funds in Brazil and finances several different programs and initiatives implemented by the MCTIC. Therefore, there is no single program or policy that depends on funds provided by the FNDCT, but rather several different ones. This feature makes it more difficult to evaluate its impact since this would involve evaluating a range of different initiatives with a variety of different objectives.

TABLE 10
FNDCT's budget execution breakdown (2015)

Total FNDCT	RS MI
Credit	1,000,000,000.00
Support to research and development in Universities and Research Institutions	550,072,995.33
Science without Borders Program (CsF)	751,686,738.94
S&T infrastructure	104,750,241.52
Equalization	198,088,198.00
Grants to firms	146,422,990.95
Equity	50,000,000.00
S&T events	2,371,552.70
Total	**2,803,392,717.43**

Source: SIOP.

Table 10 shows all of the programs and initiatives for which the fund is actually used. Historically the bulk of the fund has been used to provide grants for researchers at Brazilian universities and research institutions. The research projects supported were either individual research projects or R&D projects in partnership with companies (so-called cooperative projects). An important part of the fund has also been used to finance investments in research infrastructure across Brazilian academia.

Since the Innovation Law, in 2004, it has also been possible for the FNDCT to provide grants to companies. Part of the fund has also been used to support the credit lines for innovation overseen by FINEP. The resources from the fund feed loans provided by the Agency (FINEP), in addition to being used to equalize the interest rates charged on these loans.

It is easy to see that, over the years, the FNDCT has been used with different goals and priorities, which has resulted in a lack of consistency in the program. One example is the creation of the CsF program in 2011. Since the program was expensive and no other source of funding existed to support it, the FNDCT was used to finance scholarships in the program. In 2015, more than R$ 500 million of the FNDCT resources was used for this objective.

> While one of the main objectives of the Sectoral Funds has been to promote innovation and to improve links between science and industry, De Negri *et al*. (2009) showed that only 14% of the projects supported by the FNDCT were oriented towards business research projects, mainly with small companies. These projects account for about 35% of the total FNDCT disbursements. Despite the low participation of companies in the disbursements of FNDCT, the fund's impact on the technological efforts of Brazilian companies was considered positive (ARAÚJO *et al*., 2012), suggesting the existence of an additionality effect ZUNIGA *et al*. (2016:67).

Another issue regarding the FNDCT is the disproportionate amount of resources that are allocated to it as a contingency reserve. For instance, in 2016 the fund total was R$ 3.5 billion, but its incurred expenditure was R$ 2 billion. This happened because of the high level of reserve established by the federal government to buffer against a major fiscal crisis. Between 2010 and 2015, a reserve of more than R$ 5 billion was created.

TABLE 11
Main studies on the FNDCT

Author/year	Main objective	Method	Main findings
DE NEGRI, DE NEGRI and LEMOS (2009)	Evaluation of FNDCT on firms' technology performance	Quasi-experiment	Limit allocation of FNDCT's funds on firms. But with crowding in impact on those that were able to receive them.
LEMOS (2010)	Comparison between Brazilian excellence in scientific fields and the rest of the world	Matrix analysis of patent and employment data	Increased investment has not resulted in better performance. Disconnection between scientific production and innovation.
NASCIMENTO and OLIVEIRA (2011)	Consistency of cross-cutting actions	Qualitative exploratory analysis	Cross-cutting actions don't have co-ordination or even real governance.
ARAUJO *et al.*. (2012)	Impacts on private technology efforts	Quasi-experiment	Increase of 6.8% to 26.7% in technology efforts of participants' firms.
ALVARENGA (2012)	Impacts on private technology efforts	Dose-response function	Additionality effects. A 1% increase on public support generates 1.5% on technology private efforts.
KANNEBLEY, CAROLO and DE NEGRI (2013)	Impacts on scientific publications	Quasi-experiment	Increase of 2.4% to 7%, but mainly in national publications.

Source: Authors.

The conclusions of these studies show that the FNDCT is relevant for fueling the Brazilian ST&I system mainly in terms of university-driven activities, but that it is also important for innovative firms. Although relevant to only a small group of private firms, the studies show a certain disconnection between science financed in universities and the innovation process in companies. These studies also show a high level of dispersion with a low medium value for individual projects. So, it seems that there is significant room for improvement, mainly through increased productivity.

This led us to another relevant topic in the Brazilian ST&I system, the difficult relationship between universities and companies. As shown by Rauen and Turchi (2017) this public-private relationship (most Brazilian universities are public) is quite complex, and even with the launch of the innovation law in 2004, no straightforward process of cooperation has been established. In fact, there is limited willingness to apply the legal possibilities of this law. This is related to the high levels of risk aversion in the Brazilian public process that further complicate the execution of demand-side innovation policies. Maybe this could change with the new Decree n. 9.283/18 that stablish many legal innovations.

Demand-side innovation policies (DSIPs) use the creation and/or the stimulation of a certain demand to spur technology and innovation development. If the scholarships, credits, grants, tax incentives, or other instruments are used to guarantee that the right amount of resources is flowing to firms to produce innovation, DSIPs work as a market stimulus to fulfill the supply.

There are several ways to execute DSIPs, but the most relevant ones – in the Brazilian case – are related to pre-commercial procurements (PCPs), procurements for innovation (PPIs) and standards for innovation. The first two use the government procurement power and the last one uses the monopoly of the law.

In the Brazilian context, DSIPs are still in their infancy. Only recently have Brazilians fully understood their potential as innovation policies. In fact, as showed by RAUEN (2017), these types of policies are constrained by risk aversion in government procurement, by the lack of proper training and by the absence of specific legal mechanisms. The consequence is that DSIPs are quite marginal in the total volume of ST&I in Brazil.

Regardless, as Table 12 shows, there are a number of relevant cases in which a DSIP achieved its objectives and developed very strong technological competences. This is why DSIPs must be stimulated in the Brazilian policy mix.

On the other hand, these cases reveal that many efficiency problems need to be overcome before a more systemic approach based on DSIP can be implemented. One of the most important challenges affecting these results is erratic budgetary programming. For instance, in complex and expensive science projects, the correct flow of resources is essential for the achievement of objectives mainly due to their high-scale nature.

TABLE 12
Main studies on demand-side innovation policies (DSIPs) in Brazil

Author/year	Main objective	Method	Main findings
RAUEN, A. (2017a)	Estimating the use of civilian pre-commercial procurement for innovation in Brazil	Quantitative exploratory analysis	Low overall utilization; use lacks articulation with general S&T policy; little knowledge of its existence.
RIBEIRO (2017)	Measuring the qualitative impacts of the development (through procurement) of a new military aircraft (KC-390) on the national technology capacities	Case study. Qualitative approach with in-depth interviews and secondary data	Two prototypes developed and ready to fly; development of new skills in manufacturing engineering, machining, and embedded systems; opening of a new international market.

(Continue)

(Continuation)

Author/year	Main objective	Method	Main findings
VARRICHIO (2017)	Identifying the limits of the Partnerships for Technological Development in Health Products program as a demand-side innovation policy	Case study. Qualitative approach with in-depth interviews and secondary data	Two drugs with production technology already nationalized; low participation of national private companies; possible reduction in the purchasing price.
RAUEN, C. (2017)	Analyzing the challenges of a pre-commercial procurement for innovation in the field of complex scientific installations (SIRIUS Project)	Case study. Qualitative approach with in-depth interviews and secondary data	Project in full construction; new technological skills in the field of magnets; opening of a new international market; development of innovative financial engineering.
PELLEGRINI *et al.* (2017)	Identifying the limits to the use of traditional procurement legislation in pre-commercial procurement (Brazilian Satellite Program).	Case study. Qualitative approach with in-depth interviews and secondary data	Technology developed; geopolitical strategic gain, but with totally inadequate legal framework; risk and uncertainty are not considered in the regular procurement process.
PAMPLONA (2017)	Measuring the qualitative impacts of efficient car labeling on the behavior of automotive companies	Case study. Qualitative approach with in-depth interviews and secondary data	High and increasing levels of adoption (90% of the market) but with low impact on the consumer decision-making; insufficient to modify the technological strategy of the Brazilian automotive industry.
RAUEN, A. (2016)	Analyzing the planning and execution of the "Buy Brazilian Act" (local preference margins)	Case study. Qualitative approach with in-depth interviews and secondary data	Lack of monitoring and evaluation; lack of transparency in the definition of the sectors benefited; suboptimal execution.

Source: Rauen (2017).

Finally, regarding credit for innovation, only a few evaluation studies exist. The most relevant and recent of these are from Rauen, Saavedra and Hamatsu (Forthcoming) and Machado and Martine (2017).

According to Rauen, Saavedra and Hamatsu (forthcoming), the beneficiary companies of FINEP's credit increased their technological effort more than the increase observed in the control group. Therefore, the authors denied a full crowding out effect.

In the same way, Machado e Martine (2017) concludes: "our findings showed evidence of the positive and significant impact of BNDES credit on firms' R&D expenditures."

It is important to mention that credit for innovation is the second largest policy instrument in ST&I, but there is a robust absence of evaluation with respect to its impacts. This is a matter of concern since this form of support has grown quickly over the last ten years or so. However, it is also true that the data have only recently become publicly available.

Considering all of this, this section draws six main conclusions. First, there is an urgent need to produce additional evaluation studies, in particular regarding specific instruments like credit, equalization, and grants to firms. Second, based on the scant evidence we have so far, tax waivers need to be improved and adequately adjusted so that they are more horizontal and less concentrated on the country's largest companies. In addition, there is a need for stronger performance in terms of additionality. Third, the FNDCT loses its focus and becomes part of the regular MCTIC budget. Additionally, over the years, a disproportional part of its resources has been allocated as a contingency reserve. Since that FNDCT is the main source of ST&I in the form of public investment, this will affect the whole system. Fourth, DSIP has a huge potential to overcome socioeconomic challenges in Brazilian thought regarding technology development, but the use of DSIPs is still marginal in the overall ST&I policy. Fifth, there is an expected risk aversion behavior in the Brazilian public sector. This prevents Brazil from reaping the full benefices of the innovation law. Private and public cooperation is difficult and quite complex. In fact, the innovation law appears to have had a limited impact on innovation. Finally, credit has been shown to be relevant, but this still needs to be confirmed through additional studies.

Our overall conclusion is that, although there has been an increase in the volume and number of interventions, Brazil hasn't reaped the benefits of these changes in terms of innovation development and economic productivity. Considering this diagnosis, the following section presents recommendations to overcome the identified challenges.

5 POLICY CHALLENGES AND RECOMMENDATIONS[9]

The realization that the Brazilian federal government increased the volume of resources and the range of innovation policies without achieving meaningful results – even during the pre-crisis period when the country's economy was growing – is worrying, to say the least. This reveals the need to improve the design of these policies, but above all, to improve the institutional framework in which they operate. Since this is a policy paper, it is essential to present specific recommendations that were designed in response to the findings of this study. Our analyses allowed us to build five blocks of recommendations, which are as follows.

9. Most of the recommendations presented here were published in Portuguese in the Project "Desafios da Nação". See De Negri, Rauen and Squeff (2018) and De Negri, Araujo and Bacelette (2018).

5.1 Recalibrating the policy mix for innovation

As we have seen, there is an excessive concentration of effort on tax exemptions. International consensus suggests that this instrument, although relevant, is not the most adequate measure to support high-risk activities, especially for projects in the early stages of development.

In fact, Rocha and Rauen (2018) show that the recent tax breaks increase in the Brazilian ST&I policy mix did not enhance private R&D investment in the country.

Additionally, these tax exemptions are overly concentrated in two sectors, the automotive sector and ICTs. It is curious that the most efficient tax exemption, the *Lei do Bem*, is not sectoral but horizontal.

In this sense, it is important to recalibrate the weight of each type of intervention in order to increase the participation of instruments more appropriate to mitigating technological risks. As following:

- Ensuring the permanence of the *Lei do Bem* but with changes. Currently, the investment made in a given accounting year can only be used in the same year. This needs to change. Additionally, tax exemptions associated with investment in external R&D should be facilitated.
- Canceling exemptions that do not produce positive results and creating new horizontal exemptions that allow small- and medium-sized companies to participate.
- Increasing the relative use of grants to firms in the total policy support.
- Enhancing the use of capital investment in medium-sized companies.
- Using public procurement to implement science, technology and innovation policies.

5.2 Diversifying the Brazilian S&T system

One of the factors for the success of state-of-the-art innovation systems (for instance, the North American example) is the diversity of policies, agents and institutions forming the system. This diversity allows for the type of dynamism and competition that are essential for innovation. From this perspective, we are referring to new policies and instruments, but also new institutions and institutional models.

From the public policy perspective, despite their recent diversification, only the incorporation of instruments such as tax incentives and grants for companies (instruments that did not exist until relatively recently) can lead Brazil to significant advances in this direction.

It is necessary to create differentiated mechanisms of public support for innovation in addition to the existing models, even as a means to enable choice between them. Policies and instruments that should be developed by the public sector include the following:

- Use procurement in order to solve the real problems of Brazilian society, in areas such as healthcare, energy, education, infrastructure, etc.
- Public-private cooperation agreements (*consortiums*) to carry out R&D projects of public interest.
- Creation of public seed capital funds and/or increases to the existing FINEP and BNDES funds, which are not yet highly relevant in terms of volume of resources.
- Creation of public funds to finance ideas even when there is no available collateral.
- Fiscal or tax incentives for the creation of private seed capital funds.
- Creation of different kinds of agencies that will provide support for innovation, in addition to FINEP and BNDES (whose focus is not innovation). The recent creation of EMBRAPII, an agency inspired by the German model of the *Fraunhofer* Foundation, is a good example of the diversification of public agencies responsible for innovation. In addition, it would be interesting to create high-tech technological development agencies, similar to the North American DARPA and ARPA-E.[10]

However, institutional diversification may present the greatest challenge. Most of the country's research labs and development infrastructure exist in public universities.[11] In other words, most of the Brazilian S&T system is public and aimed primarily at education. This means the system is subject to a series of institutional restrictions, which extend from the limitations set for a public researcher to work for the private and legislation on purchases and contracts. These bureaucratic and institutional restrictions

10. Defense Advanced Research Projects Agency and Advanced Research Projects Agency-Energy's.

11. This debate and the results of a pioneering survey about the research infrastructure available in the country can be found in the following book: DE NEGRI, F.; SQUEFF, F. "Sistemas Setoriais de Inovação e Infraestrutura de Pesquisa no Brasil". Brasilia: Ipea, 2015.

represent a major obstacle for the country's R&D activities, for which institutional agility and efficiency are essential. Hence, it is necessary to

- Create differentiated operational rules (for the purchase of research material and equipment, for example) in universities and public research institutions, in order to make them more agile and competitive when they conduct high-tech research.
- Encourage and facilitate the creation of private R&D institutions, and eliminate any possible existing restrictions, so that these institutions can rely on public support when performing their research activities.
- Reinforce and consolidate differentiated models, such as social organizations, which are examples of successful Brazilian S&T models.[12]
- Create and reinforce public-private S&T investment mechanisms.
- Create real stimulus for research personnel to engage in cooperative projects with private firms.

5.3 Investing in large-scale and open research facilities

Most of Brazil's research infrastructure consists of small laboratories. Brazilian science needs a high-tech infrastructure in order to become more competitive internationally. In this case, creating a high-tech infrastructure means more than having modern and updated equipment. It means the existence of multidisciplinary and open laboratories that are large enough to take advantage economies of scale and scope in scientific production. Institutions such as FIOCRUZ, EMBRAPA, CNPEM and INPE are exceptions in the Brazilian S&T system. In this sense, our recommendations are as follows:

- Investing in the creation of large multiuser laboratories and research centers with enough capacity to produce world-class science. These institutions could be social organizations or public/private partnerships capable of operational flexibility and agility.
- Encouraging existing laboratories to become open multiuser infrastructures, with clear and transparent rules regarding the use of equipment.
- Promoting and supporting competition for scientific excellence.

12. For instance the Brazilian Synchrotron Light Laboratory and the Institute of Pure and Applied Mathematics are social organizations that are privately operated but publicly financed.

5.4 Increasing public investment in mission-oriented R&D

One of the biggest differences between public investment in R&D in countries such as the USA and Brazil is that, in the former, the main objective of public investments in R&D is to foster science *per se* rather than solving concrete problems. One of the indicators most often used in the literature to assess the level to which public investments in R&D in the country are mission-oriented is their distribution among the different ministries. Ministries with a specific mission, such as energy, defense, health, etc., tend to use investment in R&D to solve concrete problems in their respective sectors, whereas horizontal ministries, such as education or S&T have, by definition, a mission to foster science and education.

TABLE 13
Distribution of public investments in R&D, Brazil and USA (2015)

BRAZIL (MINISTRIES)	%	USA (DEPARTMENTS/ AGENCIES)	%
MCTI	36	Defense (DoD)	49
MEC	19	Health (DHHS)	23
Agriculture (Embrapa)	13	Energy (DOE)	8
Health (FIOCRUZ)	11	NASA	9
MDIC (INPI and INMETRO)	6	National Science Foundation (NSF)	4
Planning (IBGE)	6	Agriculture (USDA)	2

Source: De Negri, Rauen and Squeff (forthcoming) and NSF.

In Brazil, most public R&D is not mission-oriented. For instance, only 30% of Brazil's R&D resources are connected to institutions and ministries whose mission is to solve problems in the areas of health and agriculture. In the North American case, more than 90% of publicly funded R&D is results oriented. Thus, the suggestion here is that we maintain the budget for S&T currently overseen by the MCTI and MEC, but that we create conditions that enable sectorial ministries to foster R&D programs that are directed towards solving Brazil's concrete problems. This would involve

- Increasing the investments in R&D in sectorial ministries, such as Health, Energy, Defense, Agriculture, etc., and using these investments to solve concrete problems, such as *i)* developing medication and vaccines for SUS, the Brazilian Unified Health Care System; *ii*) developing technologies to increase energy efficiency or reduce water consumption (so as to alleviate the water crisis); *iii*) developing new telemedicine technology systems in order to increase efficiency and reduce the costs of our health care system; and *iv*) developing depollution technologies.

- Training staff in sectorial ministries on how to contract and follow up this type of investment.
- Adding explicit and clear mechanisms allowing public sector agencies to contract R&D. Article 20 of the Innovation Law already stipulates this possibility, but law needs to be improved in order to give more legal guarantees to public managers and establish new ways to contact the suppliers.
- Reinforcing policies that uses government procurement power.
- Applying demand-side innovation instruments in the innovation policy mix. The focus should extend beyond the procurement power. For instance INMETRO has a major potential to guide demand though industrial standards.

5.5 Building a more open and competitive economy

According to several existing criteria, Brazil has one of the most closed economies in the world.[13] In Brazil, the total trade flow represents just over 20% of the GDP and import tariffs (nominal or effective ones) are among the highest in the world.

However, Brazil is not only a "closed" country in terms commerce. It is also a country that is closed to ideas. The number of Brazilian students and researchers living abroad is quite small, even though this number has risen, mainly among undergraduate students, as a result of the CsF Program. The number of foreign students, researchers and industrial technicians in Brazil is even smaller. This lack of openness has implications that affect the Brazilian economy's innovation capacity in at least two major ways.

First, this lack of openness limits our capacity to follow changes on the world's technological frontier. The time it takes to incorporate state-of-the-art technology produced abroad is an obstacle to Brazil's capacity to generate relevant science and innovation when compared to international standards. Moreover, a dynamic innovation system is characterized by the constant flow of ideas and people. Due to this lack of openness, several data measures describing the world's flows of knowledge make it evident that Brazil is on the margins of these flows.[14]

13. Disponível em: <https://goo.gl/D8ooTj>.
14. See for instance <https://goo.gl/Cfp1hA>; <https://goo.gl/8gvgw4>; or <https://goo.gl/kF9xGM>.

The second aspect of the Brazil's lack of openness has to do with competition. In a capitalist economy, the engine of innovation is the search for the extraordinary profit that can be derived from new ideas. In an economy in which the market is protected from competition, the incentives for innovation are not as great. Hence, it is important for the Brazilian economy to adopt some strategies, including the following:

- Moving towards a greater openness in relation to the international market, in a gradual and transparent way, starting with segments in which the positive impacts resulting from this openness (gains in efficiency resulting from access to new technologies incorporated into some capital goods or reduction of the price of imported inputs) are greater.
- Developing incentives and mechanisms that will attract foreign researchers to work at Brazilian universities, companies and research institutes.
- Facilitating the granting of work visas to foreign professionals, with a greater focus on highly qualified workers.
- Creating swift and low-cost mechanisms (reducing tariffs whenever necessary) for importing inputs, research equipment, and prototypes.
- Prioritizing programs to send Ph.D. students and post-doctoral researchers in fields of specific interest abroad.
- Allowing public Brazilian universities to hire foreign professors.
- Encouraging learning and use of English in society as a whole, and particularly in undergraduate courses.

5.6 Improving the business environment for innovation

A complex and bureaucratic institutional environment discourages investment, especially investment in innovation. Estimates made by Ipea's team show that the impacts of an improvement in the World Bank's *Doing Business* publication on investments and productivity would be substantial.

From the perspective of innovation, these difficulties manifest themselves in many areas, including the follow: *i*) the time required for a patent to be granted; *ii*) the time and requirements necessary for approval of research or new medications by the National Health Surveillance Agency (ANVISA); *iii*) the existing restrictions on opening and closing companies; *iv*) the regulation of investments made with venture capital funds; *v*) the difficulty associated with importing inputs and research equipment;

vi) the operational difficulties involved in funding research institutions using public resources; *vii*) the difficult relationship between universities and companies; and *viii*) the time spent on due diligence.

The difficulties pointed bellow and the level at which they affect the innovation system in Brazil are diverse and require systematization. Thus, *a priori*, some basic strategies are as follows:

- Consolidating an agenda for improving Brazil's business environment and tracking progress in this area; identifying exactly which norms, regulations, and legislation could be modified in order to improve our institutional environment for innovation.
- Reformulating and modernizing the Innovation Law. A new law was created in 2016, but its paralegal instruments must be straightforward and easy to execute. Additionally, the controlling agencies must be made aware of the legal possibilities.
- Reviewing the legislation governing the opening and closing of companies in order to facilitate and expedite this process, and to encourage entrepreneurship.
- Reducing the bureaucracy associated with R&D, especially in the life sciences. In this sense, the Biodiversity Law was a step forward, but needs to be followed up and modernized frequently.
- Streamlining the process by which researchers from public institutions can develop innovation projects and offer consultancies to companies.
- Eliminating all public policy instruments that discourage innovation processes. An example is the basic production process associated with the Informatics Law, *Lei de Informática*, which establishes manufacturing norms in order for companies to have access to tax incentives. An innovation, by definition, will not be covered by the PPB.
- Jointly with control agencies, building a clear and consensual understanding with regard to the legal limits and possibilities of public managers when fostering innovation, in a way that encourages control and efficiency, but does not hinder our technological progress.

5.7 Improving the monitoring and evaluation of all innovation policies

Ongoing evaluation and monitoring of public policies is a key strategy for improving them. Therefore, all information regarding public expenditure needs to be transparent and public. Knowing how and where public funds are being used and who the beneficiaries are should be the right of every citizen.

In addition, in-course corrections and changes to interventions can only happen as long as there is total clarity regarding the direct and indirect impacts of these interventions. For this to happen, it is necessary to generate, store and disseminate reliable data.

Information related to S&T policies in Brazil is still insufficient. Concerns regarding monitoring and evaluation, despite formal recognition, are not effectively addressed in the day-to-day operations of many institutions. Computer systems in different institutions are almost unable to communicate (due to low compatibility) and evaluations (when they are performed) do not effectively feed into the policy-making cycle.

When evaluations are done, Brazil usually employs personalized initiatives (as opposed to institutionalized ones), which are capricious and don't make adequate use of the possibilities that information and communication technologies offer.

It is essential to establish a process for continually monitoring and assessing these policies, similar to the monitoring and evaluation performed by MDS on the Money Transfer Program (the *Bolsa Família* program), in other words, a system based on open data and the availability of micro-data.

Discussions concerning the monitoring and assessment of innovation policies are still fairly shortsighted in this country. Nevertheless, it is already possible to identify directions for governmental action to strengthen these processes. These include

- Intensifying the use of information and communication technologies in the collection, storage, treatment and availability of data regarding innovation.
- Legally requiring adequate evaluation of every intervention in the area of innovation in terms of period and scope (the creation of the intervention must stipulate this).

- Ensuring evaluation of the *ex-ante* impacts (i.e., requiring that each new intervention must be preceded by an assessment of its potential impacts) whenever discussions about the creation of a new intervention take place.
- Harmonizing older databases with newer ones and making them available together.

The policy challenges presented here provide just a small glimpse of the larger problem. There are structural constraints that extend far beyond the pure technological and economic aspects of this issue. For instance, Brazil has a persistent education problem that makes it difficult to embrace the new technological paradigm based on the Internet of Things (IoT). In addition, the Brazilian infrastructure erodes many of the technology gains achieved by specific firms. Brazil, in fact, has major hurdles to overcome in order to spur innovation. However, for the first time, we now have a complete understanding of how to overcome the more direct obstacles.

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