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Articles

The effects of BNDES on Brazilian pharmaceutical firms' innovation investments: a panel data approach[1]

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ABSTRACT

This paper empirically evaluates the effects of BNDES Profarma on Brazilian pharmaceutical firms, estimating the quantitative effect on its main objective, the expansion of innovative efforts. More specifically, it is of special interest to verify whether supported companies invested more in internal R&D than comparable non-supported ones. The present study combines firm-level data from the Brazilian Innovation Survey with BNDES Profarma loans information for the 2004-2014 period. Using Fixed Effects regression, we found Profarma's supported firms increased internal R&D expenditures by up to 76% and total innovation expenditures by up to 59%.

KEYWORDS | BNDES; Innovation; Panel data; Pharmaceutical, Brazil

1 The views expressed in this work are those of the authors and do not necessarily reflect those of the Brazilian Development Bank (BNDES) or its members.

Os efeitos do BNDES nos investimentos em inovação de empresas farmacêuticas: uma abordagem a partir de dados em painel

RESUMO

Este artigo avalia empiricamente os efeitos do BNDES Profarma sobre as empresas farmacêuticas brasileiras, estimando o impacto quantitativo em seu principal objetivo: a expansão dos esforços inovadores. Mais especificamente, é de especial interesse verificar se as empresas apoiadas investiram mais em P&D interno do que empresas comparáveis não apoiadas. O presente estudo combina dados em nível de empresa da Pesquisa de Inovação Brasileira com informações sobre os financiamentos do BNDES Profarma para o período de 2004-2014. Utilizando regressão com Efeitos Fixos, constatamos que as empresas apoiadas pelo Profarma aumentaram os gastos com P&D interno em até 76% e os gastos totais com inovação em até 59%.

PALAVRAS-CHAVE | BNDES; Inovação; Dados em painel; Farmacêutica, Brasil

1. Introduction

This study aims to empirically evaluate the effect of the BNDES Profarma program on the Brazilian pharmaceutical industry, highlighting its quantitative effect on its main objective: the expansion of the investment in R&D by supported firms. Fostering R&D activities is important because they are directly related to innovation and, in the long run, are responsible for generating productivity gains. Particularly in the case of the Brazilian pharmaceutical sector, the companies of which tend to be either multinationals branches or nationally owned firms with imitative behavior, the first step toward increasing innovation is to overcome the structural barrier of having a R&D workforce (RADAELLI, 2012). Therefore, it is important to assess the effects of support on R&D investment without necessarily considering the degree of innovation associated with it.

Technological innovation configures the main factor of the competitiveness of pharmaceutical industry (MALERBA; ORSENIGO, 2015). High investments in R&D activities, coupled with strong interaction with local science and technology systems, mean that industry is usually classified as high technology (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2017) and science-based (PAVITT, 1984). Moreover, as their products directly influence human health and, thus, labor productivity, it is possible to state that their innovative activities exert positive externalities on other sectors of the economy (PIMENTEL et al., 2017).

The global market structure of the pharmaceutical industry characterizes itself as an oligopoly. In this case, the leading companies operate in a broad (global) market, dedicating themselves to product differentiation by high investments in R&D. The other firms seek to establish themselves in niche markets, such as therapeutic classes, technological routes, or specific geographic spaces (HASENCLEVER et al., 2010).

However, in developing countries such as Brazil, nascent industries may find it difficult to compete with firms in the global market and may lack the capacity to accumulate such skills. Therefore, if industrial policies aim to promote the competitiveness of this industry, they should support R&D activities with specific instruments for this purpose.

In Brazil, before the 2000s, the pharmaceutical industry's market share used to be concentrated in multinational companies, which focused on marketing rather than on R&D activities. Domestic firms focused on specific niches, mainly low-cost, low-technology drugs. So, the problem faced by the domestic pharmaceutical industry lies in its small scale, which makes high expenditures on R&D and innovation unfeasible. Multinational companies, on the other hand, operate on a larger scale and have no incentive to engage in this type of spending in Brazil (NISHIJIMA et al., 2014). However, the last two decades have shown significant changes in the institutional environment: trade opening of the sector; adherence to the Agreement on Trade-Related Aspects of Intellectual Property Rights, the New Patent Law (1996), and Generic Law (1999); the creation of the Brazilian Health Regulatory Agency (Anvisa) (1999); and the prioritization of the sector in explicit industrial policies from 2004 onward (GOMES et al., 2014). In this context, the Brazilian Development Bank (BNDES) created a specific program for the industry, the BNDES Support Program to Develop the Health Industry (BNDES Profarma), which aimed to promote the sector's technological trajectory.

This study combines firm-level data from the (Brazilian Institute of Geography and Statistics) IBGE Innovation Survey and BNDES contracting information in the Profarma program in a panel from 2004 to 2014. This period was chosen because it corresponds to the phase with the highest number of program operations and includes available IBGE data. A regression based on fixed effects found that the BNDES Profarma increased expenditures in internal R&D activities by up to 76.3% and in all innovative activities by the beneficiary companies by up to 58.8% when compared with Brazilian pharmaceutical firms that received no such support. These results assume that the selection bias in access to Profarma support primarily stems from firm characteristics that remain constant over time that apply to a sample largely composed of large firms, which are predominant in the IBGE database.

This study is divided into eight sections, including this Introduction. Its second section describes the stylized facts about the pharmaceutical industry as an economic sector and about the evolution of the Brazilian pharmaceutical industry. The third section offers the logic behind the Profarma interventions and the main objectives that guided the construction of the research questions. Next, we discuss the empirical literature on policies to support innovation and their impacts in Brazil. Then, the following sections describe the database, the estimated models, and their results. The last section discusses policy implications and the current future research agenda.

2. Context

The pharmaceutical industry is the economic sector that researches, develops, and manufactures medicines and vaccines for human and veterinary use[2], belonging to the Health System value chain (GADELHA,

2 Support under BNDES Profarma was limited to companies operating in the human pharmaceutical sector.

2003). From a microeconomic perspective, this sector is characterized by a wide set of market failures. On the demand side, medicines are considered credential goods, and there is asymmetric information and principal-agent problems in the relationship between manufacturers, institutional payers, physicians, and patients. Asymmetric information inhibits the substitution between drugs with the same purpose, which undermines competition among manufacturers. Furthermore, many cases include inelastic demands, especially for life-saving treatments. As a result, these products have low substitution effects (SCHERER, 2000). The supply side faces entry barriers, such as patent protection and high regulatory requirements in industrialized economies (FIUZA; LISBOA, 2003). Pharmaceutical industry constitutes a sector in which patents configure particularly effective means to knowledge appropriation (LEVIN et al., 1987). Finally, it is important to mention the issue of scale. The pharmaceutical industry has been concentrated since its inception, and, since the mid-20th century, it has faced regulatory barriers that have further restricted it. (CHANDLER JUNIOR, 1990).

Competition is based on R&D investments, which classifies the industry as science-based (PAVITT, 1984) and with high technological intensity (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2017). Also, imitation strategies are based on R&D, such as “me too” drugs, incremental innovation, and generic drug development (MALERBA; ORSENIGO, 2015). Major pharmaceutical clusters occur in industrialized countries in connection with extensive pools of knowledge and competences in the field. Thus, companies and countries who seek to join the pharmaceutical competitive landscape must find ways to build this kind of knowledge and competences, increasing local R&D investments (LINDMAN et al., 2008).

Back in the 1990s, the Brazilian pharmaceutical industry activities were mostly commercial. Global multinationals dominated the local market by imports, acting as traders disconnected from their more innovative global activities. The inexpressive local pharmaceutical companies were based on a restricted portfolio of low cost “me-too” drugs, which have failed to encourage greater innovation efforts. The R&D

intensity remained below 0.5% up to 2003, (the year in which the first data is available), the same level of the overall Brazilian manufacturing industry, a poor result for a high-tech industry (BASTOS, 2005).

In 1999, a new institutional framework was built for the sector, with the approval of the generic drugs law and the creation of a new regulatory agency, Anvisa, inspired in highly regulated markets agencies such as the North American Food and Drug Administration and the European Medicines Agency. In the early 2000s, the central debate of the new industrial policy, known as PITCE[3], revolved around how to increase company R&D investments.

The 2000s and the first half of the 2010s may be considered the golden age of the Brazilian pharmaceutical industry. Led by generic drugs and income redistribution policies, the drug market grew yearly at two-digit Real rates. Also, Brazilian companies achieved nearly two thirds of the market share by 2014, whereas they had less than a third in the beginning of 2000s. Also, pharmaceutical firms' R&D intensity[4] grew to 2.2% in 2014, whereas general manufacturing rate grew only to 0.7% (REIS et al., 2017). Thus, while unintended, the generic drug regulation impacted the market structure, favoring domestic companies due to the large increase in market share and the small increase in R&D and innovation investments (CALIARI; RUIZ, 2014). It is worth noting that this period of growth in the domestic pharmaceutical industry coincides with a time of imbalance for Big Pharma at the international level, marked by institutional, regulatory, and technological disruptions – such as the advent of biotechnology and new laboratories (MALERBA; ORSENIGO, 2015). It is also important to highlight that Brazil has a public structure for production and research comprising universities and laboratories that plays a prominent role in the sector (GADELHA et al., 2003). The private Brazilian pharmaceutical sector was small and served a specialized audience, operating on a low scale, which contributed to limiting its R&D activities (RADAELLI, 2012).

3 For more details on the Industrial, Technological, and Foreign Trade Policy, see Mazzucato and Penna (2015) and Capanema and Palmeira Filho (2004).

4 Internal R&D expenditures over net sales revenue.

3. BNDES Profarma

In 2004, BNDES created a targeted loan program with special conditions that specifically aimed at the pharmaceutical industry: BNDES Profarma[5]. It was open to any pharmaceutical company that would invest in Brazil, not being restricted to national firms. Moreover, this targeted loan program financed specific types of investment, especially capital and innovation items, such as the construction of new facilities, machinery modernization, company R&D staff's salaries, and research goods and services. Besides, the BNDES team monitors the destination of its resources throughout its firmed contracts. Finally, special financial conditions were common at BNDES at that time as the Brazilian Government set BNDES interest rates below the average risk-free treasury bill to foster investments[6].

The program has three major phases: the first (2004-2008), second[7] (2009-2013) and third (2013-2016). In the first two phases, its stated key objectives involved (i) fostering the compliance of local manufacturing to new Anvisa regulations, (ii) increasing local medicine production, (iii) increasing local R&D activities, (iv) strengthening local firm economic and technological competences and (v) mitigating the pharmaceutical value chain trade deficit (CAPANEMA et al., 2008). Later, the program reduced its intended scope in its third version, focusing on innovation and productivity and including a biotechnology catch-up objective that goes beyond the scope of this study.

5 This section is based on literature review on the program, published in BNDES journals and in interview with the program manager.

6 For example, in 2007, the Brazilian Government set the Long-Term Interest Rates to 6.25% p.y., whereas the average Brazilian treasury interest rate that year varied from 11 to 13% p.y.

7 The second phase expanded the targeted firms, including the Medical Devices sector, introducing the concept of the Health Industry Complex. For the sake of this study, we focused only on the pharmaceutical industry.

Following its key objectives, the program had two main subprograms[8] called "innovation" and "production." This distinction was associated to several types of investment and financial conditions. Lower interest rates and longer maturities were associated with the "innovation" subprogram, which supported use items such as company R&D staff's salaries and goods and services for research activities. On the other hand, the "production" subprogram was associated to machinery modernization and new facility construction. This subprogram had less favorable financial conditions than the "innovation" one, despite the low interest rates of the latter. This meant that the program focused on proper internal R&D investments, but also considered broad innovation investments, such as firm modernization and productivity. Nevertheless, following the innovation international consensus, the "production" subprogram may be considered innovation since machinery modernization and new firm manufacturing facilities are considered in the Oslo Manual (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2018).

Another key operational issue relates to the nature of the financing supported by the innovation subprogram. Since innovation involves high uncertainty and often discontinued projects, BNDES developed an "innovation plan" support approach. In this modality, the contract states no specific drugs or projects for funding. The company would describe its innovation strategy and forecast projects for funding, which could change. BNDES monitors use items (R&D team, innovation inputs, etc.) rather than specific development projects.

4. Literature review

Public support for firm R&D investments stands among the oldest innovation policies (linked to the linear innovation model of the early 1950s). Its rationale is based on a diagnosis of firm

8 Other subprograms, such as exports, restructuring, and support to state-owned labs had very low number of contracts, as we will show in this study.

R&D underinvestment that results from low firm R&D investment appropriation and the desirable spillover effects of business R&D. Thus, it is compatible with a broad range of economic traditions, ranging from neoclassical market failure to innovation systemic failures approaches (CUNNINGHAM et al., 2016). Additionally, failures also occur in the financial market for innovative projects due to information asymmetries between lenders and borrowers as the latter would have more information about the associated risk than the former (HALL; LERNER, 2010). Public support for innovation may be described as indirect (such as tax incentives) or direct (such as grants and targeted loans). The expected chain of events may be described as follows: public support to firm R&D would increase the overall R&D invested by that firm. Thus, that firm would develop more new products and create more innovation related jobs and the increased firm innovation efforts would increase new product revenues in most cases, leading to the growth of that firm.

An alternative dynamic for this relationship is explored by the Quintuple Helix model (CARAYANNIS; CAMPBELL, 2010). According to this model, the government, universities, and companies jointly finance a new project. From this project, a start-up emerges, classified as a private investment. As the start-up grows, it is either acquired or becomes part of a large pharmaceutical group. In other words, the initial R&D phase relies on public and private funding, and separating these sources is not particularly meaningful. In this context, innovation should be viewed as systemic rather than divided between public and private investments.

From the macroeconomic perspective, higher overall R&D investments may be related to higher probability of economic gains, such as higher labor productivity, exports, and knowledge intensive jobs (CUNNINGHAM et al., 2016). Those expected effects may be grouped in two categories: those that are readily measurable (such as firms' total R&D expenditure, firm growth, profitability, and R&D employment) and intangible outcomes (such as skills, innovation capabilities, and spillover effects).

In the case of pharmaceuticals, public support for R&D investment is driven by motivations that go beyond economics. Issues such as the environment, safety, health, among others, are key topics on the public policy agenda (ZHANG et al., 2017). More specifically, certain themes emerge as objectives aimed at promoting social well-being, such as cancer treatment, AIDS prevention, safer medications, and public healthcare systems – especially in the context of pandemics.

In a wide scope systematic review of the impact and effectiveness of government support for R&D and innovation with studies on the European Union, OECD Countries, China, and Taiwan from 2003 to 2017, Petrin (2018) found that the evidence is slightly positive for the public support of firms R&D expenditures, which means input additionality. However, it is inconclusive whether public support crowds out private investment. In the pre-2000 studies, the evidence seems to fail to reject the crowding-out effects, whereas post-2000 results favor crowding-in hypothesis. This divide seems to be grounded on methodological differences between the two sets of research since most of pre-2000 empirical works used no techniques to control for endogeneity, selection bias, and unobservable heterogeneity. Thus, the state-of-the-art of the evidence rejects the crowding-out effect, suggesting that public support to R&D has crowding-in private R&D investments at the firm level.

The evidence also suggests that policy design influences results. For example, firm size is a critical issue: policies that target small and medium-sized enterprises usually have positive results. When the policy includes larger firms, results usually become inconclusive or even negative. However, in such cases, the nature of the projects tends to differ. While small and medium-sized enterprises tend to pursue incremental innovations, large firms typically aim for radical innovations. Therefore, investing in smaller firms may be more advantageous, but these firms tend to select lower-risk projects. On the other hand, larger companies can undertake larger-scale innovations, with greater effects on aggregate productivity (AGHION; HOWITT, 1990). Thus, it is important to keep in mind the social returns that justify public incentives for investments of varied sizes. Another prominent issue of policy design refers to the intervention: generally speaking, grants, subsidies, and loans perform better than tax incentives (PETRIN, 2018). This occurs due to the inherent uncertainty in this type of investment since grants, subsidies, and loans imply better risk-sharing arrangements between the public sector and the private company.

Regarding sectoral differences, Lee (2011) found that public support tends to positively affect private R&D for firms in industries with high technological opportunities and market competition. On the other hand, while controlling for sectoral differences, the author found no differential effects on firm size and age (LEE, 2011).

In the specific case of the pharmaceutical industry, several intervention initiatives have been evaluated by the empirical literature, especially in the world's largest economies (United States, Europe, and China). Eger and Mahlich (2014), analyzing a panel of European firms, found that drug price regulation reduced R&D investment in the sector, despite a non-linear relationship. Moretti and Wilson (2014) observed that R&D subsidies and tax credits in the U.S. biotechnology sector increased the number of scientists, employees, and firms, although they had no significant effects on wages or patents. Hu et al. (2021) found negative effects on R&D investment resulting from the Volume-Based Procurement policy, which aimed to reduce drug prices in China. Wei et al. (2022) found that a Chinese law that facilitated the registration and regulation of generic drugs increased R&D investment by producers. Xia (2022) found that innovation subsidies and tax refunds fostered innovation outcomes among Chinese pharmaceutical firms.

The empirical literature on the impact of Brazilian innovation policies has grown. Regarding studies on firm R&D intensity, De Negri et al. (2006) rejected the crowding-out hypothesis for Brazilian Innovation Agency (FINEP) loans, observing positive effects ranging from 28 to 39% using data from 1996 to 2003 and a Propensity Score Matching approach. This result was reinforced by Avellar (2009), who estimated effects of 106% on R&D expenditures from all FINEP instruments (tax incentives, loans, and grants) using the same approach and data up to 2005. Araujo et al. (2012) measured the impact of grants on R&D employment, showing that R&D employment in the treated group grew at a higher rate than those in the control group by 26.7 percentage points. Also, using firm-level data on the innovation activities of BNDES' supported firms and fixed effect approach (FE), Machado et al. (2017) rejected the crowding-out effects, finding an increase in firm R&D expenditures from 30 to 40% in different specifications. On the other hand, Rocha (2015) found that firms that received any kind of government support failed to increase their R&D intensity (defined as the ratio between R&D expenditures and sales revenue). The available evidence suggests that differing government policies produce varying results for the same outcome.

Focusing on the Brazilian pharmaceutical industry, Centro de Gestão e Estudos Estratégicos (2017) built a qualitative innovation competence model and applied it to a sample of national pharmaceutical companies. They found that the surveyed Brazilian companies had well-established internal manufacturing, generic drug development, and incremental innovation capabilities. For radical drug innovation, they found a few, usually outsourced, initiatives.

Regarding BNDES Profarma, Pieroni et al. (2011) used survey and descriptive statistics to discuss the program's contribution to innovation efforts. They found that the firms supported by BNDES Profarma had high levels of manufacturing compliance and grew their own R&D and innovation investments when compared to the overall sector.

In synthesis, the international empirical literature on public support to innovation suggests that it increases private firm R&D investments. The evidence on Brazilian specific programs also finds similar effects. For the pharmaceutical industry, the reviewed studies found a positive scenario of growing R&D competences and investments. Nevertheless, the available evidence for this economic sector fails to isolate the effect of BNDES Profarma on local R&D investments, the purpose of this study.

5. Data

5.1 Database

We used firm-level data to carry out our empirical strategy based on two sources: the Brazilian Innovation Survey (Pintec) from IBGE and a database of BNDES Profarma loans. Pintec/IBGE aims to explore and measure the innovative activities developed by Industrial and selected Services sectoral companies and to monitor their evolution over time. Pintec follows the conceptual and methodological guidelines of Oslo Manual of Organisation for Economic Cooperation and Development (1997), which makes Pintec data comparable to other international innovation surveys.

Pintec is triennially published by IBGE. In each of its version, the qualitative variables in its questionnaire refer to a three-year period: that of the survey year and the previous two. For quantitative variables, such as R&D expenditures, the Pintec reference year precisely refers to the year of the survey.

Pintec only surveys Brazilian formal companies with 10 or more employees. Its survey sample design is restricted to manufacturing, extractive, electricity and gas, music editing and recording, internet data processing and hosting, telecommunications, information technology, architecture, engineering, and R&D testing and technical analysis services. For manufacturing companies with 500 or more employees and service companies with 100 or more employees, Pintec is a census survey. For companies below those thresholds, it is a sample survey. Its sample design is defined to represent the target population of Brazilian firms according to previously defined selection criteria[9].

9 The Pintec sample design explores information available from other Brazilian sources in the National System of Innovation to adequately represent innovation at a more aggregate level. Examples of those sources of information include companies that have received

The logical structure of the Pintec questionnaire follows a division into blocks of questions according to the research topics of interest. The first block refers to the general characteristics of the company (such as number of employees, payroll, costs, and revenue). The second block targets the firm's innovative profile. We offer a sample split: for firms that claim to have made product and/or project innovation or have incomplete or abandoned innovation projects, the research explores the company's innovative activities. For those who have neither innovated nor had innovative projects (which correspond to about half of the annually surveyed firms), the questionnaire only relates to the last block of questions (innovation problems and obstacles). For innovative firms, the next research blocks involve the description of innovative activities, their financing, the purchase of external R&D activities, the execution of internal R&D activities, the impact of innovative activities in the company, sources of information, interinstitutional cooperation, government support, and the non-formal protection methods available[10].

In its turn, BNDES data were to funding comprising information about firms' Profarma loans contracted over 2004-2014. It is important to note that the BNDES Profarma credit program is fully included in BNDES statistics for innovation loans. Therefore, we considered its innovation project line and fixed capital acquisition lines as both types of investment are related to total innovation expenditures in the pharmaceutical sector. We found that BNDES Profarma had 119 financing-level operations with 47 companies in this whole period; 38% of which received innovation loans, and 23% took credit for innovation and fixed capital lines. It is important to note that the database mainly covers the first two phases of Profarma since the third and last phase started only in 2013.

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any governmental support for innovative efforts and companies that have declared to conduct formal R&D efforts and that have applied for patents.

10 Information on continuous variables of innovation efforts and results was discarded for firms that declared to be non-innovative and/or lacking or incomplete innovation projects. Such a procedure was necessary since this information would be counter-intuitive in view of Pintec's own logical structure.

Table 1 shows descriptive statistics of BNDES data regarding firms funded by BNDES Profarma credit lines over the three-year periods in the Pintec structure. We note that the number of loans increased from 14 in 2004-2005 to 30 in 2012-2014. The contracted total amount, in turn, increased from BRL 117 million to BRL 1.3 billion in the same period. Specific operations to support innovative activities comprised 29% of the operations and 45% of the total value contracted in that period (which showed a growing trend). This table also shows 2004-2014 firm loan value distribution statistics. The mean value of the distribution of loans for firms increased over the period, from BRL 8.4 million to BRL 43.4 million at the end of the interval.

TABLE 1
Distribution of BNDES Profarma Loans per firm over time

Triennial	N	Total	N Inov	Total Inov	Mean	S.D.	P25	p50	P75
2004-2005	14	116,947	14.3%	19.6%	8,353	9,629	2,014	5,906	11,513
2006-2008	43	810,030	18.6%	10.3%	18,838	46,371	2,021	4,842	13,688
2009-2011	32	588,356	34.4%	69.2%	18,386	29,582	2,921	5,924	16,307
2012-2014	30	1,303,449	43.3%	58.1%	43,448	59,213	10,823	20,507	46,313
TOTAL	119	2,818,782	28.6%	45.1%	23,687	44,839	2,990	8,786	20,620

Notes: BNDES loans in BRL thousand current values. Source: BNDES.

However, due to the right-skewed loan amount distribution, we find that the median is far below the mean for each year from 2004 to 2014. For instance, the loan median was BRL 4.8 million in 2006-2008, whereas the mean, BRL 18.8 million. The median loan to support firm innovation varied from BRL 2 (in 2004-2005) to BRL 20.5 million (in 2012-2014). The last quartile from 2011 onward showed a steep growth of loan distribution.

5.2 Data preparation

This study used the Pintec 2005, 2008, 2011, and 2014 survey years to build a firm-level panel data for the 2005-2014 period. To evaluate firm eligibility to the program, the sample of Pintec data was restricted to pharmaceutical firms. More specifically, the sample was restricted to firms classified in Division 21 of the National Classification of Economic Activities[11], which refers to the manufacture of pharmaceuticals within the manufacturing industry. According to IBGE, this division comprises the manufacture of pharmaceutical products, medicines, and other products, such as bandages and antiseptic preparations.

Another restriction in this study regards the innovation effort variables. Since this work aims to assess the effects of crowding in and crowding out of the intervention on companies, we decided to restrict these variables to their positive values. Moreover, the greatest interest of its evaluation lies on the level of investment in R&D from firms rather than on the decision to invest[12].

We aggregated BNDES data by company and loan year, building a firm-level BNDES Profarma data for the 2004-2014 to be merged with the Pintec panel. To maximize the number of BNDES Profarma supported firms in each Pintec year, we matched the annual BNDES data information to the closest subsequent one according to the Pintec year (for instance, we matched the 2012, 2013, and 2014 BNDES firm-level data to that for the 2014 Pintec year). We then merged both firm-level panels to obtain the final dataset for the 2003-2014 period, for which we estimated the models in the last section.

Then, we built our treatment variable: "BNDES." The dummy assumes a 1 if a firm had access to BNDES Profarma innovation credit in the current Pintec year, doing so for all subsequent data years (deeming it 0 otherwise). This choice was based on two considerations:

11 The Brazilian National Classification of Economic Activities is the classification officially adopted in Brazil to produce statistics by type of economic activity. Public Administration uses it to identify economic activities in legal entity registrations. By providing a standardized basis for collecting, analyzing, and disseminating statistics on economic activities, it can compare economic national source statistics between themselves and national data with international ones (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2007).

12 This approach tends to be conservative regarding the potential size of the effects as it includes no potential effects on the extensive margin.

first, Profarma finances the innovation plans of companies rather than specific innovation projects (which require several years until completion). Second, Profarma may have long-term effects on innovation investment outcomes based, for example, on the view of firms' process of accumulating internal capabilities and knowledge for innovation.

Profarma can support various initiatives from pharmaceutical companies in Brazil via credit operations, including investments to expand and modernize production R&D capacity and to adapt products and processes to regulatory standards (CAPANEMA et al., 2008). Therefore, five indicators of input additionality were drawn up. First, Total Innovation Expenditures (TIE), defined as the sum of all expenditures of the firm related to innovation[13]. Second, Total R&D Expenditures (RDE), both internal and external to the firm. Third, Internal R&D Expenditures of the firm (IRDE). Fourth, Equipment Expenditures (EE), that is, the sum of expenditures to acquire machinery and equipment. Fifth, firm Other Expenditures (OE) on innovation, defined as total innovation expenditures less R&D and capital goods expenditures. This category includes expenses with acquiring software and external knowledge and training labor and introduction of technological innovations in the market.

Our control variables include firm size indicators such as Employment and Labor Productivity (the ratio of gross production value to firm employment). Finally, the firm's Financing Obstacles were controlled for: the companies interested in innovation that reported financial difficulties as barriers to innovation.

A problem in this research refers to sample outliers. They stem from the very few firms with very high values for the continuous variables whose performance may distort the estimates for the sample. This problem was solved by transforming all the continuous variables in the regressions to a logarithmic format.

13 The Pintec survey defines this variable as the sum of expenditures on internal and external R&D activities; acquisition of external knowledge, software, machinery, and equipment; training; introduction of technological innovations to the market; industrial design; and other technical production and distribution preparations.

5.3 Data description

Table 2 shows the descriptive statistics at the firm level for some of the variables of Pintec. The final dataset comprises 739 observations of firms, with a mean of 185 per year. The firms supported by BNDES Profarma account for 73 observations over the whole period. Table 2 also compares the means and standard deviations of some innovation indicators and control variables in the models by treatment status. We see major differences between firms supported by BNDES and non-supported ones. In general, treated companies tend to sell, employ, and invest more in R&D activities. Finally, supported firms are more likely to receive other forms of public support and to engage in innovative activities.

TABLE 2
Descriptive statistics of firm characteristics by treatment status

Treatment Status	Non-supported		BNDES Profarma	
	Mean	S.D.	Mean	S.D.
Total Innovation Expenditures	7,836	22,587	39,298	53,875
R&D Expenditures	3,415	11,139	27,070	37,721
Internal R&D Expenditures	2,613	7,755	21,377	29,754
Equipment Expenditures	1,886	7,032	4,390	20,244
Other Expenditures	2,536	9,359	7,837	15,253
Total Sales	143,473	308,322	463,368	623,917
New Product Sales	27,441	95,051	162,582	326,458
Employment	329.1	451.7	1,380	1,292
Labor productivity	248.4	291.0	288.9	172.6
Other Public Support (dummy)	0.379	0.486	0.839	0.371
MSME firm (dummy)	0.696	0.460	0.247	0.434
Any innovation (dummy)	0.628	0.484	0.849	0.360
Product innovation (dummy)	0.477	0.500	0.795	0.407
Process innovation (dummy)	0.468	0.499	0.726	0.449
Product and process innovation (dummy)	0.318	0.466	0.671	0.473
Financing Obstacles (dummy)	0.443	0.497	0.463	0.502
Obstacles to Innovation (dummy)	0.643	0.480	0.677	0.471
Number of firms	666		73	

Notes: Monetary variables in BR$ thousands. Source: Pintec and BNDES.

Those substantial differences stem from the pattern of selection to access BNDES Profarma. As investment in innovation activities is very risky, larger companies tend to be more willing to carry out such activities. Also, despite several special financial conditions for BNDES innovation lines, such as reduced threshold for applying for direct support and lower interest rates, BNDES credit risk policy still tends to favor larger companies to reduce potential losses. Thus, one can argue for a selection bias in support allocation that favors larger firms.

Table 2 shows that the share of average R&D expenditures in relation to total innovation expenditures in supported companies revolves around 70%, whereas the share of internal R&D in relation to total R&D, almost 80%. That shows the relevance of internal R&D for the included companies.

6. Empirical strategy

This section describes the empirical approach to estimate Profarma effects on selected innovation investment outcomes of treated companies. We aim to model the effects of Profarma's low-interest loans on the level of innovation investment in pharmaceutical companies funded by the program. The decision about the innovation investment level of firms in this industry depends on a set of explanatory variables at the firm level, such as the expected return of the innovation plan, the ability of the entrepreneur (both unobserved), and observed covariates such as company size, labor productivity and market power.

Furthermore, evidence suggests more severe financing constraints on innovation investment in less developed capital markets, such as the Brazilian one (HALL, 2002; CZARNITZKI, 2006). If this is the case, innovation investment will also depend on the availability of external funding to the company. Consequently, in the absence of external funding or depending on its costs, firms' innovation investment level might be restricted to their availability of internal funding, causing firms to underinvest. So, the availability of public finance, such as that of BNDES, might help to alleviate firms' financial constraints for innovation investment, thus raising their level.

Hence, we condition our model of firm innovation investment on access to BNDES Profarma loans as our measure of firms' access to external financing. In a causal context, if the parameter associated with Profarma access is positive and significant, we find evidence of crowding in effects of Profarma on the intensive margin of firms' innovation investments. Such evidence would thus corroborate the view that firms face financing constraints to fund innovation investment.

The main endogeneity issues arise from the fact that we have neither a random or experimental sample of treated companies. Instead, pharmaceutical firms self-select themselves into application to the Profarma treatment based on observable and unobservable factors. Additionally, BNDES carries out a risk analysis to select applicants into treatment.

Firms' access to Profarma loans is positively correlated with observable factors associated with company performance and low-risk profile, such as company size; earnings before interest, taxes, depreciation, and amortization; low debt level; and so on. Firm access is also positively correlated with unobserved time-invariant factors, like the ability of its entrepreneurs or board and unobserved time-varying factors (such as, for example, firms' expected profits associated with their innovation plan). As a result, treated units suffer from positive selection bias, causing the overestimation of Profarma effects (ANGRIST AND PISCHKE, 2008).

The empirical strategy this study adopted to reduce selection bias tried to control for those factors that determine selection into treatment. We used a fixed-effect model to control for the time-varying observable components in Pintec's data and all the time-invariant unobservable components that affect selection. Moreover, the fixed-effect term of the model can control the observed but fixed determinants of those decisions[14]. Ideally, we should include balance-sheet components to control for company risk but those variables are unfortunately unavailable in the Pintec survey. Our results, however, are robust regarding several different specifications on the set of controls variables.

Nevertheless, the FE model can suitably estimate the case in which most of the selection on unobservable problem comes from omitted but fixed individual components (ANGRIST AND PISCHKE, 2008). In our case, it is difficult to believe that time-varying unobservable factors, such as the expected return associated with a company's innovation plan, would fail to raise concerns regarding selection bias. Thus, we interpret our FE estimates as an intermediate step in the pursuit of more causal evidence.

We estimate Profarma effects on innovation investment outcomes based on Equation 1.

$$Y_{it} = \beta Profarma_{it} + X_{it}^{'} + \alpha_i + \rho_t + \varepsilon_{it} \quad (1)$$

In which Y_{it} measures a firm innovation expenditures in year *t* and $Profarma_{it}$ is a dummy variable that assumes 1 if a firm *i* had access to BNDES innovation credit in year $s \leq t$ and 0 otherwise. This definition of the treatment dummy implies that the correlations estimated by β captures contemporaneous and lagged effects of Profarma[15]. Additionally, $X_{it}^{'}$ is a vector of control variables that includes a measure of firm size *Log(Employment)*, a measure of productivity[16] *Log(Labor Productivity)*, and the *Financing Obstacles* dummy[17] to control financing constraints. Moreover, α_{it} are the individual-specific fixed effects, ρ_t is year-specific effects (which may control for any macroeconomic effects), and ε_{it} is the error term.

14 Other studies in the abroad literature have used the same methodology to address similar issues: Eger and Mahlich (2014), Moretti and Wilson (2014), and Xia (2022).

15 Although we acknowledge the possibility of lagged effects, we were uninterested in this version of the study in separating those effects in the employed specification.

16 Productivity was calculated as the value added per employed person.

17 *Financial obstacles* is a dummy variable for firms that reported facing difficulties or obstacles to innovation projects due to a lack of appropriate funding sources.

7. Results

This section describes the estimates of Profarma's effects on several innovation outcomes of the financed pharmaceutical companies. We first show the estimates for the RDE and IRDE variables, as those are the primary focus of the program. Then, we comment on the estimates for the remaining desegregated innovation expenditures variables.

Table 3 shows Profarma's estimates for the R&D outcomes. We show basic ordinary least squares (OLS) references for each variable, followed by FE estimates. The first FE estimates ignore the Financing obstacles dummy added in our preferred specification (columns 3 and 6) to control for financial constraints.

TABLE 3
Profarma Effects on R&D outcomes

	Log(RDE)			Log(IRDE)		
	POLS	FE	FE	POLS	FE	FE
	(1)	(2)	(3)	(4)	(5)	(6)
Profarma	0.839***	0.599	0.451	0.806***	0.837**	0.763**
	(0.241)	(0.409)	(0.409)	(0.242)	(0.348)	(0.354)
Log(Employment)	0.968***	0.723**	0.707**	0.890***	0.583*	0.580*
	(0.0816)	(0.319)	(0.284)	(0.0793)	(0.320)	(0.304)
Log(Labor Productivity)	0.401***	0.192	0.149	0.396***	0.0456	0.0280
	(0.127)	(0.218)	(0.218)	(0.126)	(0.197)	(0.198)
Financing obstacles			-0.354*			-0.164
			(0.186)			(0.186)
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	319	319	319	308	308	308
R-squared	0.602	0.371	0.385	0.602	0.424	0.428
Number of firms		184	184		177	177

Robust standard errors in parentheses.
* p<0.1. ** p<0.05. *** p<0.01. **Source:** Authors

We see that Profarma's estimates are positive and significant for the OLS basic estimates and quantitatively large (around 80%) for the RDE and IRDE variables. The FE estimates for the RDE variable, although positive, are insignificant. For the other side, the FE estimates for the IRDE outcome are positive, significant, and sizeable. The FE estimate for our preferred specification (column 6) shows that Profarma supported companies invested roughly 76% more in internal R&D activities than non-supported ones. The positive effects for IRDE are very important from the perspective of the Profarma effectiveness goals as the program explicitly stated that the development of internal R&D capabilities as one of its primary priorities.

Table 4 shows Profarma's estimates for the innovation efforts outcomes unrelated to R&D. We see that Profarma positively and significantly affected (at the 10% level) Total Innovation Expenditures (TIE) of the supported pharmaceutical companies for our preferred specification (column 3). The size of the effect totals about 60%, lower than that for the IRDE variable, but still substantial.

Still, the Profarma coefficients estimated using FE for the other two variables, Other Expenditures on innovation (OE) and Equipment Expenditures (EE), were not significant. This indicates that Profarma financing was unable to significantly impact the complementary innovation expenditures of supported companies, although, as expected, it increased total innovation investments.

In sum, the results in this section support the view that Profarma effectively fostered innovation efforts in the Brazilian pharmaceutical sector. From the perspective of its intervention logic, its incentives aimed to stimulate firms' innovation investment and the within-companies in Section 3. The positive effects for the IRDE variable indicate that in the absence of the program, pharmaceutical firms would have had a lower level of R&D investment. This result can also be interpreted as evidence of input additionality of Profarma, associated with crowding-in effects on IRDE. The results are consistent with Lee (2011), Moretti and Wilson (2014), and Xia (2022) regarding the importance of public support for R&D investments by firms.

It is important to highlight that this study has specific features when compared with the studies above. Lee (2011) observed crowding-

TABLE 4
Profarma Effects on other innovation efforts outcomes

	Log(TIE)			**Log(OE)**			**Log(EE)**		
	POLS	**FE**	**FE**	**POLS**	**FE**	**FE**	**POLS**	**FE**	**FE**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
Profarma	0.442*	0.516	0.588*	0.971**	0.311	0.374	0.0727	-0.032	-0.255
	(0.251)	(0.322)	(0.341)	(0.434)	(0.703)	(0.704)	(0.320)	(0.481)	(0.529)
Log (Employment)	0.996***	0.740*	0.732*	0.618***	2.220**	2.207*	0.667***	-0.077	-0.099
	(0.064)	(0.386)	(0.385)	(0.150)	-1.107	-1.124	(0.091)	(0.824)	(0.782)
Log(labor Productivity)	0.453***	0.085	0.098	0.708**	1.040	1.052	0.412***	-0.534	-0.538
	(0.105)	(0.294)	(0.288)	(0.276)	-1.208	-1.205	(0.109)	(0.514)	(0.470)
Financing obstacles			0.194			0.122			-0.474
			(0.187)			(0.424)			(0.392)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	441	441	441	365	365	365	294	294	294
R-squared	0.586	0.126	0.131	0.230	0.079	0.079	0.340	0.017	0.037
Number of firms		246	246		213	213		193	193

Robust standard errors in parentheses.
* p<0.1. ** p<0.05. *** p<0.01.
Source: Authors

in effects of R&D for firms in sectors with high technological opportunities, including (but not isolating) the pharmaceutical sector. Moreover, that study analyzed data at a single point in time, which limits its consistency in terms of causal inference. This study, on the other hand, follows the same firms over time, controlling for their individual fixed effects. This panel data estimation methodology was also used by Moretti and Wilson (2014) and Xia (2022). Moretti and Wilson (2014) examined the effects of R&D tax credits and subsidies provided by U.S. state governments on the biotechnology sector. They found positive effects on the number of firms in the sector, their growth, and their innovation efforts. However, their study used state-level data rather than firm-level data, as in this study. Xia (2022) analyzed the effects of similar policies in China, focusing on innovation outcome indicators (patents) rather than on crowding-in effects of private R&D investment.

In the Brazilian context, our findings are in line with De Negri et al. (2006), Avellar (2009), Araujo et al. (2012), and Machado et al. (2017) – who found positive effects of public support on innovation investment – and against Rocha (2015), who found no significant effects of any type of government support on firm R&D intensity. In this case, it is important to emphasize that this study differs from the others by focusing on an innovation support program within a specific industrial sector. Furthermore, there are differences across studies regarding the type of funding analyzed. Financial support via loans was evaluated by De Negri et al. (2006) in the case of FINEP and by Machado et al. (2017) in the case of BNDES innovation credit. Araújo et al. (2012) studied the effects of grants from sectoral funds. The remaining studies examined different forms of support in an integrated manner, either restricted to FINEP instruments (tax incentives, loans, and grants), as in Avellar (2009), or in an unrestricted way, as in Rocha (2015).

Any consideration as to whether specific types of support are associated with greater effects on firm innovation efforts lie beyond the scope of this study, despite the international evidence that forms of intervention offer better risk sharing between the public sector and the supported firm (such as loans, subsidies, and grants) and tend to perform better (PETRIN, 2018). This may be the case for Profarma due to its operational characteristics (PIERONI et al., 2011). On the other hand, the hypothesis that the magnitude of BNDES Profarma's effects on internal R&D expenditures is related to the characteristics of the pharmaceutical sector – a highly technology-intensive industry[18] - is particularly promising and warrants further research.

Some of the differences in the magnitude and statistical significance of the results in this study may be explained by its methodology[19]. De Negri et al. (2006), Avellar (2009), and Araújo et al. (2012) applied

18 See Pavitt (1984), Malerba and Orsenigo (2015), and Lindman et al. (2008).

19 This point was also observed in a review of international empirical evidence (PETRIN, 2018).

propensity score matching techniques to construct a control group resembling the treatment group in terms of observable characteristics. However, this method restricts samples to comparable firms, which may undermine the statistical inference of the estimated results. Additionally, Avellar (2009) did not control for firm fixed effects in their estimates, which may have contributed to the larger magnitude of the calculated effect. Finally, Rocha (2015) constructed a control group based on eligibility criteria for government support but also did not control for fixed effects and used a different outcome variable, related to R&D intensity. In the case of the present study, methodology based on matching on observable characteristics was not applied because the firms in its control group were all eligible for support under BNDES Profarma. Moreover, here the same firms were observed at different points in time, controlling for their fixed effects controlled for, and estimating a wide set of outcome variables related to innovation efforts.

Nevertheless, we must further investigate the absence of effects on RDE. The fact that the IRDE mean on the treaded sample represents roughly 80% of the RDE mean, as in Section 5, raises the question regarding why we also found no positive and significant effects on the RDE variable. One possible investigation is to estimate Profarma's effects on External RDE, to evaluate a substitution effect driving the pattern of the obtained results[20].

8. Conclusion

This study is the first to evaluate a specific Brazilian sectorial program aimed at developing R&D capabilities in supported companies within a technology-intensive sector, namely the pharmaceutical industry. Moreover, it uses a comprehensive desegregated set of outcome variables to estimate the impacts of Profarma on the innovation efforts of supported companies.

20 Although available in Pintec, we avoided including this variable in the analysis as it failed to constitute an explicit outcome of the program.

This study contributes to the literature on industrial policy evaluation and innovation financing. Furthermore, it assesses a relevant sectoral program regarding funding volume, with clear links to other public policies for the sector and a structured result framework that benefits from partial evaluation and feedback. Moreover, the program lasted for roughly 12 years, providing a long period for evaluation in a context of continuous improvement of the intervention (the program underwent three revisions during this period). Taken together, these elements give this evaluation considerable potential for institutional learning. It is also valuable from the standpoint of transparency and accountability in the public policies executed by BNDES.

The main conclusion is that Profarma was relevant to determine the level of internal R&D investment of companies supported – its targeted below-market loans were positively correlated with internal R&D intensity in pharmaceutical firms. This means that the program was effective in terms of its goals, although this study examined none of its costs. It is noteworthy that we find significant results in the context of an exceptionally low sample of treated companies (slightly below 50 in the whole period). Also, the obtained evidence is relevant as it is the first in the Brazilian literature on industrial policy evaluation for the pharmaceutical sector. Moreover, since the pharmaceutical sector is a technology intensive industry, the observation of such positive effects is especially relevant in the context of a developing country like Brazil.

In terms of policy implications, the results indicate that special financing conditions regarding price, project size, collaterals, and risk policy may have contributed to the obtained evidence, although we are unable to determine which flexibility introduced by the program mattered more.

It is important to highlight that the results in this study assume that all selection biased regarding firms' access to Profarma support stem from unobserved fixed-over-time factors. This assumption seems realistic given that support is self-selected based on the innovation plans submitted by applicants. However, if the ability to design strong plans depends on factors that vary over time, finding the causal effect of support would require adopting appropriate methodologies for such cases, such as instrumental variable estimation. It is also important to mention that, due to the small number of firms supported by Profarma in the Pintec database (most of which are large companies), it was impossible to conduct a heterogeneity analysis of the impact of support by firm size.

This was the first set of results about Profarma effectiveness. Future research agenda is concerned about expanding the set of variables to include effects on innovation sales and firm growth. On the other hand, it is important to estimate the economic costs of the program so we can discuss its cost-effectiveness. Finally, it would be very important to understand the way the underlying financing conditions relate to effects.

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Data Availability Statement

The data used in this study come from two distinct sources, subject to different access regimes. Information on BNDES Profarma operations is publicly available and can be obtained from databases released by BNDES itself, ensuring transparency regarding the characteristics of the financing analyzed.

In contrast, firm-level data from the Brazilian Innovation Survey (Pintec), conducted by the Brazilian Institute of Geography and

Statistics (IBGE), are protected by statistical confidentiality under current legislation. Access to these data is restricted and requires the submission and approval of a research project by IBGE, with access granted through secure facilities or specific authorized access modalities. For this reason, the Pintec microdata used in this study cannot be made publicly available.

Declaration of Editor Responsible for the Evaluation Process

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References

AGHION, P.; HOWITT, P. A model of growth through creative destruction. Cambridge: National Bureau of Economic Research Nber, 1990. (Working Paper, 3223).

ANGRIST, J. D.; PISCHKE, J. Mostly harmless econometrics: an empiricist's companion. New Jersey: Princeton University Press, 2008.

ARAÚJO, B. C. et al. Impactos dos fundos setoriais nas empresas. Revista Brasileira de Inovação, Campinas, v. 11, p. 85-112, 2012.

AVELLAR, A. P. Impacto das políticas de fomento à inovação no Brasil sobre o gasto em atividades inovativas e em atividades de P&D das empresas. Estudos Econômicos, São Paulo, v. 39, n. 3, p. 629-649, 2009.

BASTOS, V. D. Inovação farmacêutica: padrão setorial e perspectivas para o caso brasileiro. BNDES Setorial, Rio de Janeiro, v. 22, p. 271-296, 2005.

CALIARI, T.; RUIZ, R. M. Brazilian pharmaceutical industry and generic drugs policy: Impacts on structure and innovation and recent developments. Science & Public Policy, Oxford, v. 41, n. 2, p. 245-256, 2014.

CAPANEMA, L. X. L.; PALMEIRA FILHO, P. L. A cadeia farmacêutica e a política industrial: uma proposta de inserção do BNDES. BNDES Setorial, Rio de Janeiro, v. 19, p. 23-48, 2004.

CAPANEMA, L. X. L.; PALMEIRA FILHO, P. L.; PIERONI, J. P. Apoio do BNDES ao complexo industrial da saúde: a experiência do Profarma e seus desdobramentos. BNDES Setorial, Rio de Janeiro, v. 27, p. 3-20, 2008.

CARAYANNIS, E. G.; CAMPBELL, D. Triple Helix, Quadruple Helix and Quintuple Helix and how do knowledge, innovation and the environment relate to each other?: a proposed framework for a trans-disciplinary analysis of sustainable development and social ecology. International Journal of Social Ecology and Sustainable Development, Hershey, v. 1, n. 1, p. 41-69, 2010.

CENTRO DE GESTÃO E ESTUDOS ESTRATÉGICOS. Competências para inovar na indústria farmacêutica brasileira. Brasília: CGEE, 2017.

CHANDLER JUNIOR, A. D. Scale and scope: the dynamics of industrial capitalism. Cambridge: Harvard University Press; Belknap Press, 1990.

CUNNINGHAM, P.; GÖK, A.; LARÉDO, P. The impact of direct support to R&D and innovation in firms. In: EDLER, J. et al. (Org.). Handbook of innovation policy impact. Cheltenham: Edward Elgar Publishing, 2016. p. 54-107.

CZARNITZKI, D. Research and development in small and medium-sized enterprises: the role of financial constraints and public funding. Scottish Journal of Political Economy, Edinburgh, v. 53, n. 3, p. 335-357, 2006.

DE NEGRI, J.; LEMOS, M. B.; DE NEGRI, F. Impact of P&D incentive program on the performance and technological efforts of brazilian industrial firms. Washington, DC: Inter-American Development

Bank; Office of Evaluation and Oversight, 2006. (OVE Working Papers, 1306).

EGER, S.; MAHLICH, J. C. Pharmaceutical regulation in Europe and its impact on corporate R&D. Health Economics Review, Heidelberg, v. 4, n. 1, p. 1-9, 2014.

FIUZA, E.; LISBOA, M. Bens credenciais e poder de mercado: um estudo econométrico da indústria farmacêutica brasileira. Brasília: Instituto de Pesquisa Econômica Aplicada, 2003. (Texto para Discussão, 0846).

GADELHA, C. A. G. The health industrial complex and the need of a dynamic approach on health economics. Ciencia & Saude Coletiva, Rio de Janeiro, v. 8, n. 2, p. 521-535, 2003.

GADELHA, C. A. G.; QUENTAL, C.; FIALHO, B. C. Saúde e inovação: uma abordagem sistêmica das indústrias da saúde. Cadernos de Saude Publica, Rio de Janeiro, v. 19, n. 1, p. 47-59, 2003.

GOMES, R. P. et al. O novo cenário de concorrência na indústria farmacêutica brasileira. BNDES Setorial, Rio de Janeiro, v. 39, p. 97-134, 2014.

HALL, B. H. The financing of research and development. Oxford Review of Economic Policy, Oxford, v. 18, n. 1, p. 35-51, 2002. http://doi.org/10.1093/oxrep/18.1.35.

HALL, B. H.; LERNER, J. The financing of R&D and innovation. In: HALL, B. H.; ROSENBERG, N. (Org.). Handbook of the economics of innovation. Amsterdam: North-Holland, 2010. v. 1, p. 609-639.

HASENCLEVER, L. et al. Economia industrial de empresas farmacêuticas. Rio de Janeiro: E-Papers, 2010. 194 p.

HU, Y. et al. Will the volume-based procurement policy promote pharmaceutical firms' R&D investment in China? An event study approach. International Journal of Environmental Research and Public Health, Basel, v. 18, n. 22, p. 12037, 2021.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE. Classificação Nacional de Atividades Econômicas – Versão 2.0. Estrutura detalhada e notas explicativas. Rio de Janeiro: IBGE, 2007.

LEE, C.-Y. The differential effects of public R&D support on firm R&D: theory and evidence from multi-country data. Technovation, Amsterdam, v. 31, n. 5, p. 256-269, 2011.

LEVIN, R. et al. Appropriating the returns from industrial research and development. Brookings Papers on Economic Activity, Washington, DC, v. 1987, n. 3, p. 783-831, 1987.

LINDMAN, J.; TIMSJÖ, J.; ÖZBEK, N. Looking over the shoulders of giants: a study of the geography of big pharma R&D and manufacturing operations. Stockholm: Vinnova, 2008.

MACHADO, L.; MARTINI, R. A.; DA GAMA, M. M. Does BNDES innovation credit boost firms' R&D expenditures? evidence from brazilian panel data. Rio de Janeiro: Produção BNDES – Artigos, 2017. 16 p. (Working Paper).

MALERBA, F.; ORSENIGO, L. The evolution of the pharmaceutical industry. Business History, Liverpool, v. 57, n. 5, p. 665-687, 2015.

MAZZUCATO, M.; PENNA, C. C. The rise of mission-oriented state investment banks: the cases of germany's kfw and brazil's bndes. Brighton: University of Sussex, 2015. (SPRU Working Paper Series, 2744613).

MORETTI, E.; WILSON, D. J. State incentives for innovation, star scientists and jobs: Evidence from biotech. Journal of Urban Economics, New York, v. 79, p. 20-38, 2014.

NISHIJIMA, M.; BIASOTO JUNIOR, G.; LAGROTERIA, E. A competição no mercado farmacêutico brasileiro após uma década de medicamentos genéricos: uma análise de rivalidade em um mercado regulado. Economia e Sociedade, Campinas, v. 23, n. 1, p. 155-186, 2014.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT. EUROSTAT. Oslo Manual 2018: guidelines for collecting, reporting and using data on innovation. 4. ed. Paris: OECD Publishing, 2018.

ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT. OECD science, technology and industry scoreboard 2017: The digital transformation. Paris: OECD Publishing, 2017.

PAVITT, K. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy, Amsterdam, v. 13, n. 6, p. 343-373, 1984.

PETRIN, T. A literature review on the impact and effectiveness of government support for R&D and innovation. Brussels: ISIGrowth, 2018. (Working Paper, 5/2018).

PIERONI, J. P.; PEREIRA, R. O.; MACHADO, L. Metodologia de monitoramento e avaliação do BNDES: uma aplicação para o programa BNDES Profarma. BNDES Setorial, Rio de Janeiro, v. 33, p. 315-348, 2011.

PIMENTEL, V. P. et al. Sistema de saúde brasileiro: gestão, institucionalidade e financiamento. BNDES Setorial, Rio de Janeiro, v. 46, p. 7-77, 2017.

RADAELLI, V. Trajetórias inovativas do setor farmacêutico no Brasil: tendências recentes e desafios futuros. 2012. Tese (Doutorado) - Instituto de Geociências, Universidade Estadual de Campinas, Campinas, 2012.

REIS, C. et al. Panoramas setoriais 2030: indústria farmacêutica. In: BANCO NACIONAL DE DESENVOLVIMENTO ECONÔMICO E SOCIAL (Org.). Panoramas setoriais 2030: desafios e oportunidades para o Brasil. Rio de Janeiro: BNDES, 2017. p. 137-146.

ROCHA, F. Qual o efeito do apoio governamental à inovação sobre o gasto empresarial em P&D? Evidências do Brasil. Revista Brasileira de Inovação, Campinas, v. 14, p. 37-60, 2015.

SCHERER, F. M. The pharmaceutical industry. In: PAULY, M. V.; MCGUIRE, T. G.; BARROS, P. P. (Org.). Handbook of health economics. Amsterdam: Elsevier, 2000. v. 1, p. 1297-1336.

WEI, Y. et al. The impact of the consistency evaluation policy of generic drugs on R&D investment intensity of pharmaceutical companies—An empirical study based on the difference-in-differences model. Frontiers in Public Health, Lausanne, v. 10, p. 902025, 2022.

XIA, Y. The impact of R&D subsidies on firm innovation in different supervision situations: analysis from pharmaceutical companies in China. Technology Analysis and Strategic Management, Abingdon, v. 36, n. 8, p. 1792-1809, 2022.

ZHANG, M.; PAWAR, K. S.; BHARDWAJ, S. Improving supply chain social responsibility through supplier development. Production Planning and Control, London, v. 28, n. 6-8, p. 500-511, 2017.

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