The Effects of BNDES on Brazilian Pharmaceutical Firms' Innovation Investments: a Panel Data Approach*

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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%.

JEL classification: D04; O31
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1 Introduction

The objective of this article is to empirically evaluate the effect of BNDES Profarma on the Brazilian pharmaceutical industry, highlighting the quantitative effect on its main objective, the expansion of firms' innovative efforts. More specifically, it estimates whether companies supported by the program invested more in internal R&D activities than non-supported ones.

The pharmaceutical industry has in its technological innovation its main factor of competitiveness (Malerba & Orsenigo, 2015). High investment in R&D activities, coupled with strong interaction with local science and technology systems, mean that industry is usually classified as high technology (OECD, 2017) and science-based (Pavitt, 1984). Moreover, as their products directly influence human health, and consequently, labor productivity, it is possible to affirm that their innovative activities exert positive externalities on other sectors of the economy (Pimentel *et al.* , 2012).

From the structural point of view, at the global level, the pharmaceutical industry is characterized as an oligopoly, in which the leading companies operate in a broad (global) market, dedicating themselves to product differentiation through high investments in R&D. The other actors seek niche markets as in therapeutic classes, technological routes or specific geographic spaces (Hasenclever *et al.* , 2010).

However, in developing countries, such as Brazil, local pharmaceutical firms face entry barriers to compete with firms in the global market, and may therefore not be able to accumulate skills for innovation. Therefore, if industrial policy is to promote the competitiveness of this industry, it should support within-company R&D activities with adequate instruments for this purpose.

In Brazil, before the 2000s, pharmaceutical industry's market share used to be concentrated by multinational companies, which focused on marketing rather than on R&D activities. National firms were dedicated to specific niches, mainly low-cost, low-technology drugs. However, the last two decades have been marked by significant changes in the institutional environment: trade opening of the sector, adherence to the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and New Patent Law (1996), Generic Law (1999), creation of Anvisa (1999) and prioritization of the sector in explicit industrial policies from 2004 on (Gomes *et al.* , 2014). In this context, BNDES created a specific program for the industry, BNDES Profarma, whose aim was to promote sector's competitiveness.

The present study combines firm-level data from the IBGE Innovation Survey with BNDES contracting information by the Profarma program, in a panel from 2004 to 2014. Using a regression based on fixed effects, it was verified that the BNDES Profarma was able to increase the expenditures in internal R&D activities by up to 76.3% and by up to 58.8% the expenditures in all innovative activities

by the beneficiary companies.

This article is divided into eight sections, including the Introduction. The second section presents the stylized facts about the pharmaceutical industry as an economic sector and about the evolution of the Brazilian pharmaceutical industry. In the third section, we present the logic of Profarma's intervention, its main objectives, which guided the construction of the research questions. Next, we discuss the empirical literature on policies to support innovation and the available evidence of such policy's impact in Brazil. Then, the following sections presents the description of the data used, the models and the results obtained. The last section discusses policy implications and presents future research agenda.

2 The Pharmaceutical Industry

Pharmaceutical industry is the economic sector that researches, develops and manufactures medicines and vaccines, being part of the Health System value chain (Gadelha, 2003). From a microeconomic perspective, the market 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 among manufacturers, institutional payers, doctors and patients. In the supply side, there are barriers of entry, such as patent protection and high regulatory requirements in industrialized economies (Fiuza & Lisboa, 2003). Pharmaceutical industry is usually cited as the main sector in which patents are effective means to knowledge appropriation (Levin, 1987).

Competition is based on R&D investments, which classifies the industry as science based (Pavitt, 1984) and of high technological intensity (OECD, 2017). Also imitation strategies are based on R&D, such as "mee too" drugs, incremental innovation and generic drug development (Malerba & Orsenigo, 2015). Major pharmaceutical clusters are found 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 though imports, acting as traders, disconnected from their more innovative global activities. Local pharmaceutical companies were inexpressive, based on a restricted portfolio of low cost "me-too" drugs, that have not encouraged a greater innovation effort. The R&D intensity was below 0.5% until 2003, first data available, 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 drug law the creation of a new regulatory agency, Anvisa, inspired in highly regulated markets agencies such as the North-American Food and Drug Administration (FDA) and the European Medicines Agency (EMA). In early the 2000s, increasing firms R&D investments was at the center of the new industrial policy debate, known as PITCE.[1]

The 2000s and 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 a two digits real rates. Also, national companies achieved nearly two thirds of market share by 2014, when they had less than a third in the beginning of 2000s. Also, pharmaceutical firm R&D intensity grew to 2.2% in 2014, while general manufacturing rate grew only to 0.7% (Reis *et al.* , 2017). Thus, while unintended, the generic drug regulation had an impact on the market structure, favoring domestic companies both in terms of market share (large increase) and in R&D and innovation investments (small increase) (Caliari & Ruiz, 2014).

3 BNDES Profarma

In 2004, BNDES created a low-interest targeted loan program specific for the pharmaceutical industry, known as BNDES Profarma[2]. As other BNDES credit lines, it was open to any pharmaceutical company that would invest in Brazil, not being restricted to national firms. Also, it's a targeted loan program because it financed specific use items, focused mostly in capital and innovation investments, such as construction, machinery modernization, firm R&D team salary and research goods and services. Besides, BNDES team monitors the destination of the resources all over the contract. Finally, the low interest rates were common at BNDES at that time, because the Brazilian Government set the BNDES interest rates lower than the average risk free treasury bill to foster investments.[3]

The program has three major phases: the first (2004-2008), second[4] (2009-2013) and third (2013-2016). In the first two phases, it's stated key objectives were: (i) foster the compliance of the local manufacturing to new Anvisa regulations;

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

[2]This section is based on literature review on the program, published in BNDES journals and in interview with the program manager

[3]For example, in 2007, the Brazilian Government set the Long Term Interest Rates was 6.25% p.y and the average Brazilian treasury interest rate that year varied within 11% p.y. and 13%p.y.

[4]The second phase expanded the targeted firms, including the Medical Devices sector, introducing the concept of Health Industry Complex. For the sake of the paper, we focused only in the pharmaceutical industry.

(ii) increase medicines local production; (iii) increase local R&D activities; (iv) strengthen local firms economic and technological competences and; (v) mitigate the pharmaceutical value chain trade deficit (Capanema *et al.* , 2008). Latter, in its third version, the program reduced its intended scope, focusing on innovation and productivity. It also included a biotechnology catch-up objective, which will not be discussed in the present paper.

Following its key objectives, the program had two main subprograms[5], called "innovation" and "production". This distinction was associated to different use items and financial conditions. Lower interest rates and longer maturities were associated with "innovation" subprogram, which supported use items like firm R&D team salary and research goods and services. On the other hand, "Production" subprogram was associated to machinery modernization and new facilities construction. This subprogram had not as good financial conditions as "innovation" subprogram, although still considered low interest rates. This meant that the program focused on proper internal R&D investments, but also considered broader 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 to the firm manufacturing facilities are considered in the Oslo Manual (OECD & Eurostat, 2018).

Another key operational issue relates to the nature of the financing supported by the innovation subprogram. Since innovation involves high uncertainty and often projects fail and are discontinued, BNDES developed an "innovation plan" support approach. This means that the contract does not state specific drugs or projects to be financed. The company would present its innovation strategy and a forecast of projects to be financed, but those could be changed. BNDES monitors the use items (R&D team, innovation inputs etc), not specific development projects.

4 Literature Review

Public support to firms' R&D investment is among the oldest innovation policies, linked to the linear model of innovation of early 1950s. Its rationale is based on a diagnosis of firm R&D under-investment that results of low firm R&D investments appropriation and desirable spillover effects of business R&D. Thus, it's compatible with a broad range of economic traditions, ranging from neoclassical market failure to innovation systemic failures approaches (Cunningham *et al.* , 2016).

[5]Other subprograms, such as exports, restructuring, and support to state-owned labs had very low number of contracts, as we will show in latter within this article

Additionally, there's also market failure in the financial market to innovative projects due to information asymmetries between lenders and borrowers, who'd have more information about the associated risk then lenders (Hall & Lerner, 2010). This is especially relevant in developing countries such as Brazil, where capital markets are less developed. For example, Ambrozio *et al.* (2017) found evidence that Brazilian firms face financial constrains for investments in general.

Public support for innovation may be described as indirect, such as tax incentives, or direct, such in the form of grants and targeted loans. The expected chain of events may be described as following: public support to firm's R&D will increase overall R&D invested by that firm; thus, that firm would develop new products and create more innovation related jobs; the increased firm's innovation efforts would in most cases increase new product revenues, leading to the growth of that firm. At the macroeconomic perspective, higher overall R&D investments may be related to higher probability of economic gains, such as higher labour 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 (Cunningham *et al.* , 2016).

In a wide scope systematic review of impact and effectiveness of government support for R&D and innovation, covering pappers between 2003 and 2017 on European Union, OECD Countries, China and Taiwan, Petrin (2018) found that the evidence is slightly positive for public support to firms R&D expenditure (input additionality). However, it's inconclusive whether public support crowds out private investment. In pre-2000 studies, the evidence seems not to reject the crowding-out effects, while post-2000 results are more in favour of 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 did not use 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 actually crowding-in private R&D investments at the firm level.

The evidence also suggests that policy design influences its results. For example, firm size is an important issue: policies that target SMEs usually has positive results. When the policy includes larger firms, the results usually become inconclusive or even negative. Other important issue of policy design is the intervention used: generally speaking, grants, subsidies and loans performs better than tax incentives (Petrin, 2018).

Regarding sectoral differences, Lee (2011) found that public support tends to have positive effects on private R&D for firms in industries with high technological

opportunities and high market competition. On the other hand, while controlling for sectoral differences, the author did not found differential effects for firm size and age (Lee, 2011)

There is a growing empirical literature on the impact of Brazilian innovation policy. Regarding studies on firms' R&D intensity, De Negri *et al.* (2006) rejected crowding out hypothesis for Brazilian Innovation Agency (FINEP) loans, using a data between 1996 and 2003 and a Propensity Score Matching approach. This result was latter reinforced by Avellar (2009) using the same approach and data until 2005.

Araujo et al (2012) measured the impact of grants on R&D employment, showing that R&D employment of the treated group grew at a higher rate than those of the control group. Also, using firm-level data on innovation activities of BNDES supported firms for all sector and a fixed effect approach (FE), Machado *et al.* (2017) rejected the crowding-out effects, finding an increase in firms' R&D expenditures varying between 30% and 40% in different specifications. On the other side, Rocha (2015) found that firms that received any kind of government support did not increase their R&D efforts. The available evidence suggests then that different government policies have different results on the same output.

Focusing on the Brazilian pharmaceutical industry, CGEE (2017) built a qualitative innovation competences 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 initiatives, but usually outsourced.

Specifically on BNDES Profarma, Pieroni *et al.* (2011) used survey and descriptive statistics to discuss the program's contribution to innovation efforts. They found that firms supported by BNDES Profarma had high levels of manufacturing compliance and grew their own R&D and innovation investments, compared to overall sector, although they didn't implemented methods to isolate the effects.

In synthesis, the international empirical literature on public support to innovation suggests that it has has positive effects in increasing private R&D investments at firm level. The evidence on Brazilian specific programs also finds similar effects. For the pharmaceutical industry, the studies reviewed identified a positive scenario of growing R&D competences and investments. Nevertheless, the available evidence for this economic sector does not isolate the effect of BNDES Profarma on local R&D investments, which is the purpose of the present paper.

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 (Brazilian Geographic and Statistics Institute) and a database of BNDES Profarma loans. Pintec-IBGE is a firm-level data that aims to explore and measure the innovative activities developed by Industrial and selected Services sectoral companies, as well as to monitor their evolution over time. Pintec follows conceptual and methodological guidelines of Oslo Manual of Organization for Economic Cooperation and Development (OECD, 1997), which makes Pintec data comparable to other international innovation surveys.

Pintec is published by IBGE on a triennial basis and, by now, there are six available editions of Pintec: 2000, 2003, 2005, 2008, 2011 and 2014. For each version of the survey, its questionnaire refers to a period of three years for the qualitative variables: the survey year and previous two. While, for the quantitative variables, like R&D Expenditures, Pintec's reference year is precisely the year of the survey.

Pintec surveys only Brazilian formal companies with 10 or more employees. Survey sample design is restricted to manufacturing, extractive, electricity and gas, music editing and recording, data processing and internet hosting, telecommunications, information technology, architecture, engineering, testing and technical analysis and R&D services sectors. For companies with 500 or more employees (for manufacturing) and 100 or more employees for services, Pintec is a census survey and for companies below those threshold, it is a sample survey. Pintec's sample design is defined to represent the target population of Brazilian firms under those selection criteria. [6]

The logical structure of the questionnaire of Pintec follows a division by blocks of questions, according to the topics of interest of the research. The first block refers to the general characteristics of the company, such as number of employees, payroll, costs and revenues. The second block is aimed at the firm's innovative profile. Here is 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 did not innovate

[6]Pintec sample design explore information available from other Brazilian sources in the National System of Innovation in its attempt to represent adequately the innovation phenomenon at a more aggregate level. Examples of those sources of information are: companies that have received any governmental support for innovative efforts, and companies that have declared to carry out formal R&D efforts and that have applied for patents. For more details, see http://www.pintec.ibge.gov.br

and do not have innovative projects, which correspond to about half of the firms surveyed annually, the questionnaire goes directly to the last block of questions related to problems and obstacles to innovation. For innovative firms, the following research blocks involve the description of innovative activities, their financing, the purchase of external R&D activities, the realization 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.[7]

For its turn, BNDES data is a financing-level data comprising information about firms' Profarma loans contracted over the period 2004-2014. It is important to note that BNDES Profarma credit program is included as a whole in BNDES' statistics for innovation loans. Thus, we considered both its innovation and fixed capital lines, because we consider the pharmaceutical sector as being a very relevant R&D intensive sector and then would like to analyze the innovation effort behaviour of the whole supported companies. We found that BNDES Profarma had 119 financing-level operations with 47 companies in this whole period. 38% of these companies took innovation loans, and 23% took credit for both the innovation lines and the 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.

Table 1 shows some descriptives of BNDES data on firms supported by BNDES Profarma credit lines over the three-year periods defined by the Pintec structure. We note that the number of loans increased from 14 in the period 2004-2005 to 30 in the period 2012-2014. The total amount contracted, in turn, increased from BR$ 117 million to BR$ 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, with a growing trend. This table also presents loan value distribution statistics for firms during the 2004-2014 period. The mean value of the distribution of loans for firms increased over the period, going from BR$ 8.4 million to BR$ 43,4 at the interval end.

However, given the loans value distribution is right-skewed, we observe the median is far below the mean for each year from 2004-2005. For instance, the loans median were BR$ 4,8 millions in 2006-2008, while the mean were BR$ 18,8 millions. The median loan for supporting firms' innovation varied between BR$ 2 million (in 2004-2005) and BR$ 20,5 million (in 2012-2014). There is a steep growth in the last quartile of loan distribution from 2011.

[7]Information on continuous variables of innovation effort 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: Distribution of BNDES Profarma Loans over time

Triennial	N	Total	N Inov	Total Inov	Mean	S.D.	P25	P50	P75
2004-2005	14	116,947	14%	20%	8,353	9,629	2,014	5,906	11,513
2006-2008	43	810,030	19%	10%	18,838	46,371	2,020	4,842	13,688
2009-2011	32	588,356	34%	69%	18,386	29,582	2,921	5,924	16,307
2012-2014	30	1,303,449	43%	58%	43,448	59,213	10,823	20,507	46,313
Total	119	2,818,782	29%	45%	23,687	44,839	2,990	8,786	20,620

Notes: BNDES loans in BR$ thousands current values. Source: BNDES.

5.2 Data Preparation

In this paper, we used Pintec's survey years of 2005, 2008, 2011 and 2014 to build a firm-level panel data for the period 2005-2014. To condition on firms' 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 (CNAE)[8], which refers to the manufacture of pharmaceuticals within the manufacturing industry. According to the IBGE, this division comprises the manufacture of pharmaceutical products, the manufacture of medicines and other products, such as bandages and antiseptic preparations.

Another restriction made in the present study occurred in the innovation effort variables. As the work has the objective of verifying the effects of crowding in and crowding out of the intervention in the companies, it was decided to restrict these variables to their positive values. In the same way, it is emphasized that the greatest interest of the evaluation is on the level of investment in R&D of the firms, and not on the decision to invest or not.[9]

We aggregated BNDES financing-level data by company and year of the loan, so we built a firm-level BNDES Profarma data for the 2004-2014 to be merged with Pintec's panel. In order to maximize the number of BNDES Profarma's supported firms found in each year of Pintec, we matched the year information of BNDES data to match with the closest superior Pintec's year. For instance, we matched 2012, 2013 and 2014 BNDES' firm-level data years to 2014 Pintec's year. We then merged both firm-level panels to obtain the final dataset for the 2003-2014 period,

[8]CNAE is the classification officially adopted in Brazil in the production of statistics by type of economic activity. It is used by the Public Administration for the identification of economic activity in registrations and registrations of legal entity. By providing a standardized basis for collecting, analyzing and disseminating statistics on economic activity, the CNAE enables the comparability between economic statistics from different national sources and the country's statistics at the international level to be broadened (IBGE, 2007).

[9]This approach tends to be conservative in terms of the potential size of the effects, as it does not include potential effects on the extensive margin.

where we estimated the models presented in the last section.

After that, we built our treatment variable, called BNDES. The variable is a dummy that assumes 1 if a firm had access to BNDES Profarma innovation credit in the current Pintec's year and keeps assuming 1 in subsequent years of the data, being 0 otherwise. This choice was based on two considerations: first, Profarma finances innovation plans of companies, rather than specific innovation projects, which requires several years until completion. Second, it is possible that Profarma 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.

Five indicators of input additionality were drawn up. First, Total Innovation Expenditures (TIE), defined as the sum of all expenditures of the firm. 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 on the acquisition of machinery and equipment. Fifth, firm's Other Expenditures (OE), defined as total expenditures less R&D and capital goods expenditures. This category includes expenses with acquisition of software, acquisition of external knowledge, training of labor and introduction of technological innovations in the market.

Our control variables includes firm size indicators such as Employment and Labor Productivity (calculated as the ratio of gross production value to firms' employment). Finally, the firm's Financing Obstacles situation was controlled, identified by companies with an interest in innovation that reported financial difficulties as obstacles to innovation.[10]

5.3 Data Description

Table 2 shows 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 of firms over the whole period. Table 2 also compares the means and standard deviations of some innovation indicators and control variables used in the models by treatment status. We see there are large differences between firms supported by BNDES and the non-supported ones. In general, treated companies tend to invest more in R&D activities and are larger than the others in terms of sales and employment. Finally, supported firms are more likely to receive other forms of public support and to engage in innovative activities.

Those substantial differences stems from the pattern of selection to access BN-

[10]Due to the presence of outliers in Pintec's survey, we used a log transformation for all the continuous variables used in the regressions.

DES 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, like reduced threshold for applying for direct support and lower interest rates, BNDES credit risk policy still tends to favor the selection of larger companies to reduce potential losses.

Table 2 additionally reports that the share of average R&D expenditures in total innovation expenditures between supported companies is around 70%, while the share of internal R&D in total R&D is almost 80%. That reveals the relevance of internal R&D for the treated companies.

Table 2: Descriptive Statistics of firms' characteristics by treatment status

Treatment Status	Non-supported Mean	Non-supported S.D.	BNDES Profarma Mean	BNDES Profarma 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	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
Observations	666	666	73	73

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

6 Empirical Strategy

This section describes the empirical approach adopted to estimate Profarma effects on selected innovation investment outcomes of treated companies. We are interested in modelling the effects of Profarma low-interest loans on the level of innovation investment of the pharmaceutical companies financed 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 on observed covariates like company size, labor productivity and market power.

Furthermore, there is evidence of greater severity of financing constraints for

innovation investment in the context of less developed capital markets, like 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 the its costs, firms' innovation investment level might be restricted to the availability of firms' internal funding, causing firms to underinvest. In this context, the availability of public finance, like BNDES' one, might help to alleviate firms' financial constraints for innovation investment, thus raising its level.

Hence, we condition our model of firms' innovation investment level on access to Profarma loans as our measure of interest of firms' access to external financing. In a causal context, if the parameter associated to 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 with the view that firms face financing constraints to fund innovation investment.

The main endogeneity problems come from the fact that we do not have a random or experimental sample of treated companies. Instead, pharmaceutical firms self-select themselves into application to Profarma treatment based on both observables and unobservables factors. Additionality, BNDES carries out a risk analysis to select applicants into treatment.

Firms' access to Profarma loans is positively correlated with observable factors associated to companies' performance and a low-risky profile, like company size, EBITDA, low debt level, and so on. Firms' access is also positively correlated with unobserved time-invariant factors, like the ability of the entrepreneurs (or board) of the company, and unobserved time-varying factors as, for example, firms' expected profits associated to its innovation plan. As a result, treated units suffers from positive selection bias, causing overestimation of Profarma effects (Angrist and Pischke, 2008).

The empirical strategy adopted to reduce the selection bias problem is trying to control for those factors that determines selection into treatment. We used a Fixed Effect (FE) model to control for both the time-varying observable components available in Pintec's data[11] and the all the time-invariant unobservable components that affect selection. In addition, the fixed effect term of the model allows us to control also for all the observed but fixed determinants of those decisions.

Nevertheless, the FE model is a suitable estimator for the case in which most of the selection on unobservables problem comes from omitted but fixed individual components (Angrist and Pischke, 2008). In our case, it is hard to think that time varying unobservable components, as the expected return associated to the

[11]Ideally, we should include balance-sheet components to control for company's risk, but unfortunately those variables are not available in Pintec's survey. Our results however are robust to several different specification on the set of controls variables and then we chose more parsimonious ones.

company's innovation plan, would not be of concern in terms of selection bias. Thus, we interpret our FE estimates as an intermediate step in the seek of more causal evidence.

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

$$Y_{it} = \beta Profarma_{it} + X'_{it}\gamma + \alpha_i + \rho_t + \epsilon_{it} \quad (1)$$

where Y_{it} is a measure of firm's innovation expenditures in year t and $Profarma_{it}$ is a dummy variable that assumes 1 if firm i had access to Profarma in year $s <= t$ and 0 otherwise. This definition of the treatment dummy implies that the correlations estimated by β captures simultaneously contemporaneous and lagged effects of Profarma.[12] Additionally, X'_{it} is a vector of control variables that includes a measure of firm size, Log(Employment), a measure of productivity, Log(Labor Productivity), and the Financing Obstacles dummy, to control for financing constraints. α_i is the individual-specific fixed effects, ρ_t is year-specific effects and ϵ_{it} is the error term.

7 Results

This section presents the estimates of Profarma effects on several innovation outcomes of the pharmaceutical companies financed. We show firstly the estimates for the RDE and IRDE variables, once those are the primary focus of the program. After that, we comment on the estimates for the remaining desegregated innovation expenditures variables.

Table 3 reports Profarma estimates for the R&D outcomes considered. We present basic OLS references for each variable, followed by FE estimates. The first FE estimates does not include the Financing obstacles dummy, added in our preferred specification (columns 3 and 6), to control for financial constraints.

We see firstly that Profarma estimates are positive and significant for the OLS basic estimates and are quantitatively large (around 80%) for both the RDE and IRDE variables. The FE estimates for the RDE variable, however, despite being positive, are not significant. For the other side, the FE estimates for the IRDE outcome are positive and significant and also 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 found for IRDE are of very importance from the point of view of

[12] Although we recognize the possibility of lagged effects, we were not interested at this version of the paper in separating those effects in the specification employed.

Profarma effectiveness goals, as the program explicitly stated that the development of internal R&D capabilities were of primary priority.

Table 3: Profarma Effects on R&D outcomes

	Log(RDE)			**Log(IRDE)**		
	OLS	FE	FE	OLS	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<0.01, ** p<0.05, * p<0.1

Table 4 shows Profarma estimates for the innovation efforts outcomes not related to R&D. We note Profarma has positive and significant effects (at the 10% level) on Total Innovation Expenditures (TIE) of the pharmaceutical companies supported, for our preferred FE specification (column 3). The size of the effect is about 60%, lower than the one found for the IRDE variable, but still substantial.

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

In sum, the results presented in this section give support to the view that Profarma was an effective program to support innovation efforts on the Brazilian pharmaceutical sector. From the point of view of the intervention logic of the of the program, its incentives were designed to stimulate firms' innovation investments and mainly the within-company one as discussed in Section 3. The positive effects found for the IRDE variable indicates 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 to crowding-in effects on IRDE.

Table 4: Profarma Effects on other innovation efforts outcomes

	Log(TIE)			**Log(OE)**			**Log(EE)**		
	OLS	FE	FE	OLS	FE	FE	OLS	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	-0.0319	-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***	-0.0768	-0.0990
	(0.0635)	(0.386)	(0.385)	(0.150)	(1.107)	(1.124)	(0.0910)	(0.824)	(0.782)
Log(labor Productivity)	0.453***	0.0845	0.0982	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<0.01, ** p<0.05, * p<0.1

Nevertheless, we need to further investigate the absence of effects on total RDE. The fact that the IRDE mean on the treaded sample represents roughly 80% of the RDE mean, as show in Section 5, raises the question why we did not find positive and significant effects also on the RDE variable. One possible investigation is to estimate Profarma effects on External RDE (ERDE), to see if there exist a substitution effect driving the pattern of results obtained.[13]

8 Conclusion

This paper is the first one to evaluate a specific Brazilian sectoral program aimed to develop R&D capabilities in supported companies in a technology intensive sector, the pharmaceutical one. Moreover, it uses a comprehensive desegregated set of outcome variable to estimate impacts of Profarma on innovation efforts of companies supported.

The paper contributes to the literature of industrial policy evaluation and to the innovation financing literature. Furthermore, it evaluates a relevant sectoral program in terms of volume of financing, with clear links to other public policies to the sector, and with structured goals. In addition, the program lasted for roughly 12 years, which gave us a large period for the evaluation in a context of continuous improvement of the intervention (the program went through three revisions in the period). With all those elements together, the present evaluation has a considerable potential for institutional learning. Also, it is worthy from the point of view of transparency and accountability of the public policies executed by

[13]This variable, despite available in Pintec, were not included in the analysis as it was not an explicit outcome of the program.

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 we cannot yet say anything about its costs. It is noteworthy that we find significant results in a context of very low sample of treated companies. Also, the obtained evidence is of particular relevance as it is the first one in the Brazilian literature of industrial policy evaluation for the pharmaceutical sector. In addition, as the pharmaceutical sector is a technology intensive industry, the observation of such positive effects seems to be especially relevant in the context of a developing country as Brazil.

In terms of policy implications, the results indicate that special financing conditions in terms of interests and risk policy present in the program may all have had its contribution to the obtained evidence, although we cannot say which flexibility introduced by the program mattered more.

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 side, it is important to produce estimates of the economic costs of the program, so we can discuss its cost-effectiveness. Finally, it would be very important try to understand the way the underlying financing conditions relate to the effects.

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