Additionality of BNDES Loans for Innovation: Evidence from Brazilian Panel Data[†]

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Abstract: We evaluate the effects of BNDES loans support to innovation on firms' innovation efforts. We use data from the Brazilian Innovation Survey (Pintec - IBGE) for the 2005-2014 period, a firm-level dataset for within-companies innovation activities, and BNDES data on loans for innovation over this period to estimate those effects. We employed a Fixed Effects (FE) approach to estimate the effects on five innovation input outcomes. Our findings show evidence of positive and significant effects of BNDES support on firms' R&D expenditures over the analysed period. We then carry out a cost-effectiveness analysis of BNDES innovation support.

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1. Introduction

The purpose of this paper is to evaluate the effects of BNDES direct support to innovation, in the form of targeted loans, on firms' innovation efforts. BNDES support to innovation is based on the view that the innovation process results ultimately in higher levels of companies' productivity and competitiveness, hence leading to economic development. Also, because of the market failures associated to the knowledge production and the innovation financing, firms tend to underinvest in innovation (Arrow, 1962). As a consequence, there is a well-established view that public support for the innovative activities of companies could in principle lead to gains in social welfare.

Although some authors have evaluated different Brazilian public innovation instruments, mainly tax incentives and grants, there is scarce evidence on the effectiveness of targeted loans instruments for supporting firms' innovation. As BNDES is one of the most important actors in the provision of public financing in the form of loans in the Brazilian Innovation System, the present article contributes to the debate by filling this gap in the literature.

This paper uses a microeconometric approach to estimate the effects of BNDES loans for innovation on firms' input innovation outcomes. Following Cunningham et al. (2016), we define input additionality as the degree to which firm inputs to innovation increase because of the government support.

We use data from *Pesquisa de Inovação* (Pintec-IBGE) for the 2005-2014 period, a Brazilian firm-level dataset for within-companies innovation activities, and BNDES data on innovation loans over this period to estimate BNDES effects.[1] We employed a Fixed Effects (FE) approach to estimate the effects on input additionality. Our empirical findings show evidence of positive and significant effects of BNDES innovation support on firms' total innovation expenditures and R&D expenditures outcomes considered for the FE approach.

This paper is organized in five sections, including this Introduction. Section two present the literature review and the institutional background of BNDES support, with a brief description of the main BNDES loans lines and programs to support firms' innovation activities. Section three discusses the empirical strategy used to estimate the effects of BNDES on firms' innovation expenditures outcomes. Section four presents the results of our empirical strategy and a cost-effectiveness analysis of innovation support. Finally, section five discusses the main findings and its implications.

2. Background

2.1 Literature Review

The neoclassical rationale of direct support for innovation is based on the notion of market failures (Cunningham et al., 2016). Because of such failures, innovative efforts by private agents tend to occur in a suboptimal magnitude from the social point of view by two mechanisms: firstly, the semipublic characteristic of knowledge causes a lower degree of appropriability. Thus, as appropriability of knowledge is incomplete, externalities arise, which

[1] The estimates of this study were obtained in the IBGE's site destinated for researches that use confidential microdata of IBGE's official surveys - S*ala de Acesso Restrito*" (SAR-IBGE). It also uses public data on BNDES innovation loans for the analysed period, available in BNDES' website: https://www.bndes.gov.br/wps/portal/site/home/transparencia.

could lead to underinvestment in innovation activities. Secondly, the higher level of uncertainty, commonly related to innovation projects, leads to a lower degree of interest among private funds to finance such investments (Arrow, 1962).

The logic of public support for innovation, therefore, starts from the idea that the increase of firms' innovative efforts, mainly R&D, in a significant number of cases, leads to the development of new products and processes, and consequently firms' growth and productivity (Crèpon et al., 1998). In addition, it is important to consider interaction between agents and innovative networks, which might generate spillover effects (Teece, 1986). R&D spillovers may create positive externalities, such as new markets, knowledge and networks, so that they produce social gains beyond the private gains. Hence, some kind of public incentive and coordination is justified to compensate market failures and encourage private agents to interact and devote resources to innovation more than they would without this support.

In this sense, government's role in innovation policies is to reduce uncertainty, correct market failures by sharing risks and costs, and overcome inappropriabilities. It should be noted that the policy should then represent an advance in relation to the initial situation of market failure. That is, the intervention must effectively create additionality in terms of efforts (input) or results (output) by the beneficiaries (Cunningham et al., 2016).

Governments can support innovative business activities through various mechanisms. On the one hand, indirect forms of intervention involve the use of fiscal policy. On the other hand, the direct forms include specific policies to support this type of activity for companies. Direct forms of intervention include grants through non-reimbursable resources to cover the costs of R&D activities. In addition, there are credit guarantee systems by the state, as well as mechanisms to support seed capital, angel investors and venture capital. Finally, there are the soft loan systems, characterized by the use of below-market interest rates to the financing of innovation that operates through government agencies or private financial agents (Cunningham et al., 2016).

Moreover, the specialized literature and experiences of public support for innovation point out that each financing instrument adheres to a phase of the innovation process. The further away from market innovation and the greater its risk and potential for positive externalities, the greater the need for non-reimbursable or subsidized instruments. For projects with smaller technological risks and with better known return periods, equity becomes an option. However, innovation sometimes requires longer lead times to become commercially viable. In this sense, investment funds are a viable option, mainly, to support startups and small technology-based companies that develop projects within the terms and risks accepted by venture capital. Subsequently, for less risky technology staging and innovation, loans become a feasible option along with equity instruments to strengthen the company's capital[2].

The Brazilian government provides a variety of instruments to support innovation activities and promote innovation networks. Governmental resources for innovative activities increased from BR$ 15.8 billion, in 2000, to BR$ 99.6 billion, in 2016, accordingly to the Brazilian Science and Technological Ministry. Among the agents of direct support, BNDES is one of the most important in the Brazilian Innovation System, offering mainly innovation targeted soft loans for private companies (Zucoloto et al., 2019). The BNDES' soft loans instrument

[2] For more details, see: https://publications.europa.eu/en/publication-detail/-/publication/16f0f2d7-727c-11e7-b2f2-01aa75ed71a1/language-en/format-PDF/source-37290826.

consists of loans with interest rates lower than the market rate and subjected to other favourable conditions, like longer amortization schedules (Bastos, 2012).

Empirical studies that attempt to econometrically analyze the effects of innovation policies date back to the 1980s in the international literature. Those studies focus in general on estimating innovation policy's effects on firms' input additionality. The results found are generally positive, in the sense that the interventions are capable of increasing R&D expenditures by the beneficiaries[3]. For studies that focus on output additionality, the indicators of interest usually evaluated are number of patents, firms' propensity to innovate, innovation revenues and number of skilled jobs.

The Brazilian literature on the effectiveness of innovation policies also tends to focus on input additionality. For example, Avellar (2009) measured the impacts of several governmental instruments to support innovation expenditures, both direct and indirect, using data from Pintec and propensity score matching techniques. Her main results point out to significant impacts of the policies evaluated on R&D expenditures. For its turn, Kannebley and Silveira Porto (2012) and Zucoloto et al (2017) found that *Lei do Bem*, a policy of tax incentives to innovation, increased R&D expenditure for the supported firms. By focusing on the impact of grants, De Negri (2009) found positive effects on private R&D expenditures of beneficiary firms for two distinct Brazilian non-reimbursable funds.

The evidence on the effectiveness of tax incentives and grants instruments is relatively available in Brazil. For the other side, there is scare evidence for the existing loans instruments to support innovation (De Negri and Rauen, 2018). Machado et al. (2017) was the first study to focus on the impact of loans support, using data from BNDES loans. The authors found that BNDES supported companies tend to invest 40% more on R&D than non-supported comparable companies for the 2005-2014 period.

The present article continues the analyses started in Machado et al. (2017) by increasing the set of input additionality outcomes evaluated and carrying out a cost-effectiveness analysis of BNDES loans support. The cost-effectiveness discussion allows us to compare the relative eficiency of BNDES loans instrument with respect to other existing instruments, which is a central for the discussion of policy alternatives and priorities in resource allocation in the Brazilian Innovation System.

2.2 Institutional Background

Within-companies innovation support is currently a strategic priority for BNDES, as it helps companies to increase productivity and competitiveness. In a historical perspective, BNDES logic of innovation support was, before 1990s, complementary to fixed capital financing in the industrial sector (Bastos, 2012). It was only in the late 1990s that BNDES started to take a more active stance in supporting innovation, through the creation of sectoral loans programs and equity funds to support technology-based companies.

The decade of 2000 was marked by the resumption of sectoral industrial policy in Brazil. This process intensified in 2004, with the establishment of the Industrial, Technological and Foreign Trade Policy (PITCE). PITCE aimed to creating conditions for competitiveness and

[3] Cunningham et al. (2016) deeply summarizes the main evidence available on the effectiveness of innovation policy.

international insertion of the Brazilian industry, focusing on technological innovation in specific technology-intensive sectors, like the pharmaceutical one.

In the context of PITCE, BNDES launched Funtec instrument, based on non-reimbursable loans to support innovation projects of public technological institutions (ITs) carried out with private partnerships. In addition, BNDES launched horizontal loans lines to support innovation in all companies, regardless of sector, called “Linhas de Inovação”. Also, in 2004, Profarma was created to support pharmaceutical industry, a well-known intensive R&D sector.

In 2008, the Productive Development Policy (PDP) reproduced and expanded the systemic actions of PITCE. For BNDES, this meant consolidating innovation as a strategic priority (Zucoloto et al., 2019). Thus, new lines of sectoral support for innovation were created, such as the Proengenharia in 2009, to support local engineering in sectors such as automotive, capital goods, defense, oil & gas, chemical, petrochemical and shipbuilding.

From 2012 on, there was a deepening of BNDES active position in relation to the technologies to be developed by its support programs. In 2013, the Inova Empresa program was created, based on public calls for the selection of projects that would be contemplated by the BNDES support mechanism. In the same year, new sector programs were created, such as Prodesign (support for the fashion sector and brand differentiation), Procult (support to the productive chain of the culture economy) and BNDES MPME Inovadora (support for the competitiveness of micro, small and medium-sized enterprises).

In the period of this analysis, which goes from 2004 to 2014, BNDES supported innovation projects through mainly equity and soft loans instruments. Among the equity instruments, there was direct participation in the capital of the companies and privately managed venture capital funds and a seed capital investment fund, as CRIATEC. On the other hand, the loans instruments were divided in vertical ones - with sectoral soft loans programs like Prosoft, Profarma and Proengeharia, and the soft loans horizontal innovation lines, like *linhas de inovação*.

As those programs and lines were targeted ones, there were a well-defined list of items that could be financed. The lines in general used to finance equipment acquisition, training of employees, acquisition and licensing of intellectual property rights, registration of patents, trademarks, designs, general research and development activities, labor force engaged in R&D activities, etc. It is important to mention that BNDES innovation support evolved through time from the financing of individual innovation projects to the the idea of supporting firms’ innovation plans.

The logic model of BNDES innovation loans support were based fundamentally on the provision of subsidized interest rates to finance firms’ innovation investments.[4] Additionally, innovation loans used to have other attractive terms, as, for example, fixed interest rates for some programs, longer amortization and grace periods, and no collateral requirement for smaller companies and projects. Those benefits were supposed to encourage companies to

[4] In the analysed period, BNDES used to lend based on an institutional interest rate, named TJLP (*Taxa de Juros de Longo Prazo*), set quarterly by the National Monetary Council. This rate used to be the benchmark rate for BNDES loans to companies until 2017 and was considerably lower than the Selic rate, the short-term interest rate targeted by the Brazilian Central Bank.

invest in innovation projects and then increasing their level of innovation expenditures and particularly R&D expenditures (input additionality). For its turn, a higher innovation investment level was supposed to cause a higher level of innovation and then promoting firms' productivity, exports and sales (output additionality).

BNDES issued a total of 598 innovation loans to companies through 2004 to 2014. The number of loans issued increased over time, going from 10 to 106 in this period. In terms of relevance, BNDES' main sectoral programs (Profarma, Proengenharia and Prosoft) concentrated almost 60% of the operations in the period, followed by horizontal innovation lines (*linhas de inovação* and *Inovação/PSI*).

Table 1 shows the total value of loans given by BNDES to support firms' innovation activities in the 2004-2014 period. BNDES gave more than BR$ 16 billion in loans for firms during the whole period in nominal terms. The total amount of loans grew over time, mainly after 2009, coinciding with the period of BNDES expansion in the Brazilian credit market. In terms of instrument relevance, Proengenharia was the most relevant one, with almost BR$ 5 billion in operations in the whole period. The amount of Profarma's loans reached approximately BR$ 3 billion, which was roughly twice Prosoft's total. For the other side, the total amount of loans for BNDES horizontal lines (*Inovação/PSI and Linhas de Inovação*) were roughly BR$ 5 billion in the period.

Table 1: Evolution of loans value by BNDES innovation loans instruments - 2004-2014

	2004-2005	2006-2008	2009-2011	2012-2014	Total
Proengenharia	0	118,723	1,571,455	3,263,824	4,954,002
Inovação/PSI	0	0	0	3,612,915	3,612,915
Profarma	118,877	872,206	623,521	1,435,896	3,050,500
Prosoft	71,447	282,550	218,156	983,837	1,555,990
Linhas de Inovação	0	231,436	788,535	366,188	1,386,159
Others	51,557	15,290	1,464,355	384,648	1,915,850
Total	**241,881**	**1,520,205**	**4,666,022**	**10,047,308**	**16,475,416**

Notes: nominal value in BR$ thousands.
Source: BNDES.

3. Methodology

3.1. Datasets

We used firm-level data to carry out our empirical strategy based on two sources: Pintec-IBGE and BNDES. The Brazilian Innovation Survey (Pintec) from IBGE (Brazilian Geographic and Statistics Institute) 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 (Statistical Office of the European Communities, 1997), which makes Pintec data comparable to other international innovation surveys.

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 thresholds, it is a sample survey. Pintec's sample design is defined to represent the target population of Brazilian firms under those selection criteria.[5]

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 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, inter institutional cooperation, government support and the non-formal protection methods available.

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. On the other hand, for the quantitative variables, like R&D Expenditures, Pintec's reference year is precisely the year of the survey. 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.

For its turn, BNDES's data is a loan-level data comprising information about firms' innovation loans contracted with BNDES over the period 2004-2014, a total of 598 loans for almost three hundred distinct companies.[6] BNDES's innovation data considers only loans, filtering out BNDES FUNTEC and equity lines for innovation.

3.2. Data preparation

As Pintec is a triennial survey, we matched BNDES loans data with the respective Pintec's reference triennial. For instance, we matched BNDES' supported firms during 2006-2008 to the Pintec's edition of 2008 and so forth.

As BNDES finances both companies' innovation plans and specific innovation projects, which requires several years until completion, we decide to define our treatment variable accordingly. As a result, we define the treatment period for a company from the loan respective Pintec's triennial on.

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[5] Pintec sample design explores 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.

[6] BNDES Profarma loans for the financing of new plants were included in BNDES innovation dataset. This choice was based on the fact that those loans could be considered innovation in a broad sense, as the one adopted by BNDES.

Our dependent variables refer to Pintec's measures of input additionality. Five indicators of innovation effort were drawn up. First, Total Innovation Expenditures, defined as the sum of all expenditures of the firm. Second, R&D Expenditures, both internal and external to the firm. Third, Internal R&D Expenditures of the firm. Fourth, Equipment Expenditures, that is, the sum of expenditures on the acquisition of machinery and equipment. Fifth, firm's Other Expenditures, defined as total expenditures less the sum of R&D expenditures and Equipment expenditures. This variable includes expenses with acquisition of software, acquisition of external knowledge, training of labor and introduction of technological innovations in the market.

Our control variables include firms' Employment, a measure of firm size, and Labor Productivity, a measure of firm productivity. Additionally, Pintec data allow us to control for firms' access to other alternatives of public support for innovative activities (Other Public Support dummy). Finally, firm's financing obstacles to innovation, identified by companies with interest in innovate that reported financial difficulties as obstacles to innovation, were controlled by using a dummy variable to capture positive responses.

3.3. Descriptive Statistics

Table 2 reports some descriptive statistics of BNDES innovation data at the firm level. We note that the number of firms supported grows over time, from just 8 companies in 2004, to 71 in 2014. This table also presents loan value distribution statistics for firms during the 2004-2014 period. The mean of the distribution of loans for firms increased over this period, going from roughly BR$ 8.7 million to BR$ 32.5. Given the loans value distribution is right-skewed, we observe the median is far below the mean for each year. For instance, the loans median was BR$ 2.4 million in 2008, while the mean was BR$ 15.1 million. The loans median varied between BR$ 2.4 million (in 2008) and BR$ 14.8 million (in 2013). After 2009, the last quartile of the loans distribution started to remain above BR$ 20 million per firm.

Table 2: Distribution of loans value per firm

Ano	N	mean	sd	p50	p25	p75
2004	8	8,720	9,953	4,473	2,370	12,437
2005	15	11,475	13,958	5,811	3,000	13,050
2006	22	12,386	18,808	4,750	2,550	9,900
2007	30	24,490	58,809	5,717	2,350	15,828
2008	34	15,089	37,497	2,464	1,400	7,799
2009	42	19,461	35,604	4,700	2,433	23,960
2010	37	56,981	190,755	6,156	2,794	20,982
2011	36	48,343	139,893	6,205	3,668	23,750
2012	48	47,135	90,508	12,326	3,485	36,174
2013	69	79,373	193,309	14,787	5,300	71,000
2014	71	32,508	56,448	11,471	3,000	33,188
Total	**412**	**39,989**	**116,341**	**6,770**	**2,990**	**26,750**

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

Table 3 shows descriptive statistics at the firm-level for some of the variables of Pintec. The final dataset comprises 55,748 observations of firms, with a mean of 13,937 per year. The firms supported by BNDES account for 322 observations of firms over the whole period. The number of firms supported grows from 13 in 2005 to 143 in 2014. Table 3 also compares the means 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, employment and labor productivity.

Those substantial differences stems from the pattern of selection to access BNDES innovation loans. 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. For example, BNDES in general requires the companies to offer collateral for the loans, as well as audited balance sheet for contracting.

Table 3 also allows us to compare the evolution of the difference of sample means over time, for each Pintec's triennial. There is a general rising trend for the continuous variables over the period, especially from 2011 on. This trend is more evident for firms supported by BNDES and results in a crescent discrepancy between the groups of supported and non-supported firms over the triennials.

Table 3: Means comparison by treatment status over Pintec's triennials

Treatment Status	**2005**		**2008**		**2011**		**2014**	
	Non-supported	BNDES	Non-supported	BNDES	Non-supported	BNDES	Non-supported	BNDES
Employment	295	956	306	1,575	339	2,702	353	2,664
Labor productivity	162	332	202	241	205	651	266	484
Total Innovation Expenditures	4,719	42,016	5,674	39,350	5,960	85,563	7,552	95,967
R&D Expenditures	1,469	32,906	1,963	23,880	2,257	52,385	3,215	56,083
Internal R&D Expenditures	1,308	30,185	1,683	23,153	1,952	45,819	2,286	39,819
Equipment Expenditures	1,822	3,780	2,441	10,234	2,558	19,678	3,159	17,776
Other Expenditures	1,428	5,329	1,270	5,235	1,145	13,500	1,179	22,108
Total Sales	85,904	507,344	101,149	596,161	124,182	2,035,000	159,827	1,907,000
New Product Sales	27,975	109,933	29,239	145,609	38,710	904,833	62,598	981,168
Industrial firm	0.92	0.85	0.87	0.71	0.90	0.71	0.84	0.72
Other Public Support	0.27	0.83	0.27	0.69	0.39	0.94	0.43	0.91
MSME firm	0.84	0.31	0.81	0.46	0.84	0.47	0.78	0.35
Financing Obstacles	0.29	0.42	0.35	0.38	0.41	0.35	0.46	0.54
Obstacles to Innovation	0.37	0.42	0.50	0.60	0.47	0.49	0.51	0.67
Any innovation	0.51	0.92	0.47	0.91	0.46	0.86	0.49	0.87
Product innovation	0.32	0.92	0.32	0.78	0.28	0.78	0.32	0.81
Process innovation	0.40	0.77	0.39	0.71	0.40	0.77	0.43	0.78
Product and process innovation	0.22	0.77	0.24	0.57	0.22	0.68	0.26	0.72
Number of firms	**12,709**	**13**	**15,582**	**68**	**13,667**	**98**	**13,468**	**143**

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

3.4 Empirical Strategy

This section presents the empirical strategy used in this paper to estimate the effects of interest. As mentioned before, we aim to estimate the effects of BNDES direct support on the following input additionality outcomes: R&D expenditures (RDE), Internal R&D expenditures (IRDE), Total Innovation Expenditures (TIE), Equipment Expenditures (EE) and Other Expenditures (OE).

The main econometric problems associated to the estimation of those effects derive from the fact that we have sample selection problems. Once we do not have an experiment, our treated sample comes from self-selected firms, thus causing endogeneity problems in the estimation of causal effects of the treatment.

The self-selection problem is linked to both observables and unobservables factors, due to the characteristics of the innovation phenomenon and the credit analysis carried out by BNDES. It is pretty plausible that selection into treatment (access to BNDES loans for innovation) depends on the financial statements of the companies (in general observed in firms' data) and also on the ability of their entrepreneurs (unobserved in the data).

The strategy adopted to mitigate the selection problem was controlling for both observed (time-varying) and unobserved (time-invariant) confounders based on a Fixed Effects (FE) approach. The FE model is a consistent estimator in the case most of the selection on unobservables comes from omitted and fixed individual components, as its estimation allows us to eliminate this kind of firm heterogeneity. Hence, the idea is trying to approach the conditions of random assignment by controlling for those dimensions in the estimation of the following equation:

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

where Y_{it} is the log of a measure of firm's innovation input in year *t*, $BNDES_{it}$ is a dummy variable that assumes 1 if firm *i* had access to BNDES innovation loans in year $s <= t$ and 0 otherwise, and X'_{it} is a vector of control variables that includes Log(Employment), Log(Labor Productivity), the Other Public Support and Financing Obstacles dummies. Additionally, α_i is the individual-specific fixed effects, ρ_t is year-specific effects and ε_{it} is the error term. We are thus interested in estimating β, which captures the effects of BNDES loans on our input variables.

4. Results

4.1. Effects on input additionality

We now present the FE estimates of the effects of BNDES on firms' input additionality outcomes. Table 4 presents estimates for the five input outcomes of interest. Columns 1, 2 and 3 show respectively OLS, FE and FE (for the balanced sub-sample) estimates of the effects.

Table 4 shows that the BNDES effects estimates are positive and significant for the R&D Expenditures, Total Innovation Expenditures, and Internal R&D Expenditures variables for both OLS and FE estimators considered. They are indeed much greater for the OLS estimator than for the FE estimator, as expected, due possibly to the selection on unobservables problem. The FE estimates are strongly significant, at the 1% percent level, for both the R&D Expenditures and Internal R&D Expenditures variables (for the balanced sample).

Besides, the size of the effects is arguably large for the R&D Expenditures and Internal R&D Expenditures variables. They are also greater than the effects obtained for the Total Innovation Expenditures variable, which must be associated to the focus of some of the financing instruments assessed, like Profarma, on stimulating within companies R&D. For the other side, the estimates obtained for the Equipment Expenditures and Other Expenditures variables are not significant, evidencing no positive effects on those complementary variables.

For the R&D Expenditures and Internal R&D Expenditures variables, the size of the estimates are similar and show that the treated companies tend to invest about 30% more in R&D (and specifically in internal R&D) than they would in the absence of the BNDES support. The FE estimates for the balanced sub-sample show even greater impact estimates, a bit more than 40% for those two variables. It is important to note that the sample size decreases substantially when we consider just the balanced panel: for those outcomes, the number of distinct companies represents about one-quarter of those for the unbalanced sample.[9] The fact that the size of the estimates are greater for the balanced sub-sample indicates that most of the positive and sizeable effects must come from this sub-sample, which is formed by the larger companies (those surveyed in the census layer of Pintec's data).

[9] For example, the sample of treated companies is composed of 233 observations, representing 2.5% of the sample used.

Table 4: BNDES effects on input additionality

	Log(RDE)			Log(TIE)			Log(EE)			Log(IRDE)			Log(OE)		
	OLS (1)	FE (2)	FE bal. (3)	OLS (1)	FE (2)	FE bal. (3)	OLS (1)	FE (2)	FE bal. (3)	OLS (1)	FE (2)	FE bal. (3)	OLS (1)	FE (2)	FE bal. (3)
BNDES	1.498***	0.324***	0.425***	0.932***	0.237*	0.262*	-0.197	-0.0614	-0.141	1.424***	0.305**	0.412***	0.862***	0.267	0.241
	(0.111)	(0.122)	(0.140)	(0.108)	(0.127)	(0.150)	(0.142)	(0.253)	(0.301)	(0.110)	(0.122)	(0.140)	(0.214)	(0.395)	(0.511)
Log(Employment)	0.603***	0.396***	0.409***	0.740***	0.503***	0.496***	0.667***	0.345***	0.427***	0.590***	0.363***	0.362***	0.608***	0.327***	0.502***
	(0.0141)	(0.0634)	(0.0947)	(0.00941)	(0.0466)	(0.0803)	(0.0116)	(0.0668)	(0.119)	(0.0143)	(0.0637)	(0.0904)	(0.0147)	(0.0930)	(0.142)
Log(Labor	0.510***	0.290***	0.380***	0.539***	0.280***	0.419***	0.456***	0.247***	0.276**	0.476***	0.286***	0.271***	0.456***	0.214***	0.273
Productivity)	(0.0222)	(0.0600)	(0.0997)	(0.0121)	(0.0414)	(0.0875)	(0.0137)	(0.0561)	(0.121)	(0.0221)	(0.0594)	(0.0902)	(0.0168)	(0.0760)	(0.171)
Other public	0.586***	0.304***	0.299***	0.779***	0.560***	0.527***	0.411***	0.293***	0.209**	0.565***	0.290***	0.297***	0.341***	0.264***	0.157*
support	(0.0351)	(0.0536)	(0.0715)	(0.0227)	(0.0395)	(0.0566)	(0.0276)	(0.0559)	(0.0814)	(0.0349)	(0.0528)	(0.0680)	(0.0345)	(0.0653)	(0.0941)
Financing	0.225***	0.0945**	0.0902	0.303***	0.220***	0.213***	0.0607**	0.123**	0.136	0.222***	0.0814*	0.0763	0.362***	0.283***	0.266**
obstacles	(0.0342)	(0.0475)	(0.0642)	(0.0232)	(0.0381)	(0.0548)	(0.0280)	(0.0543)	(0.0831)	(0.0342)	(0.0473)	(0.0636)	(0.0341)	(0.0667)	(0.111)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed effects	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Observations	9,122	9,122	3,332	22,678	22,678	5,719	16,775	16,775	4,254	8,613	8,613	3,225	17,464	17,464	4,508
R-squared	0.455	0.142	0.161	0.465	0.065	0.059	0.362	0.022	0.021	0.453	0.149	0.172	0.241	0.013	0.014
Number of firms	6,013	6,013	1,430	15,292	15,292	2,162	12,336	12,336	1,986	5,614	5,614	1,384	12,371	12,371	1,979

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Source: Pintec and BNDES.

4.2. Cost-Effectiveness Analysis

This section introduces the discussion about the cost-effectiveness analysis of the BNDES innovation loans evaluated here. Following the definition in the literature of public support for innovation, the cost-effectiveness (CE) or additionality indicator measures the ratio between the amount of innovation expenditures generated by the policy and the policy's direct costs. For example, in the case of tax incentives policies, the indicator divides additional innovation expenditures by the net tax revenue loss (also called tax expenditures), as explicited in Mohnen and Lokshin (2009). In the case of subsidized loans, the direct costs of the policy are measured in terms of the amount of subsidies alocated in the loans (Machado et al, 2018). The cost-effectiveness indicator is expressed then by the following equation:

$$CE = \frac{Additional\ \widehat{innovation}\ expenditure}{Loans\ \widehat{fiscal}\ cost}$$

The cost-effectiveness indicator is used to order social preferences for public policies with the same objective (outcome), but it does not allow us to say if a certain policy was worthwhile, as is the case of the cost-benefit analysis. This means that the most cost-effective policies are those that require the least directly allocated public resources to generate an additional unit of impact (in the quantities of the variable). In our case, the literature considers as effective innovation policies with a cost-effectiveness greater than 1 (Mohnen and Lokshin, 2009).

Since there are still no direct estimates of the fiscal costs of innovation financing for the period evaluated, this variable will be approximated using the estimates in Machado et al (2018) for the cost-effectiveness analysis of the *Programa de Sustentação do Investimento* (PSI) program. PSI was a federal program, executed by BNDES that used to finance mainly fixed capital investments with subsidized interest rates for the period of 2009-2015.[10] Additionaly, PSI used to finance innovation investiments with subsidized interest rates. Hence, the use of those estimates as a proxy for the fiscal cost of innovation loans through the whole period of evaluation is arguably plausibe as almost 60% of the volume financed for innovation in the period evaluated refers to PSI loans.[11]

The authors' estimates show that the ratio between the policy's direct fiscal cost (to the point of view of the Brazilian Treasury) and program disbursements were 0.19 and 0.25 for the years 2009 and 2010, respectively[12]. Using the more conservative ratio for the year of 2010 and extrapolating it as our proxy for the entire period of the present analysis (a strong assumption), we can calculate the volume of subsidies allocated to the innovation loans, as shown in Table 6 below. Using sample means estimates of the level of innovation expenditures and innovation loans of companies supported, we estimate a cost-effectiveness ratio well above the unit cost (respectively 1.65 and 2.17 for TIE and RDE outcome variables). Although it is based on a proxy on the costs of the policy, estimates indicate, therefore, in the direction of a very effective support in the period.

[10] The fiscal cost of PSI loans is defined as the present value of the net fiscal cost to the government with implicit and explicit subsidies (associated with Treasury resources). These costs vary mainly with the rate fixed for PSI innovation loans and with changes in the Selic rate forward structure at the time of borrowing. For more details on calculations, see section 6 of Machado et al (2018).

[11] Most of the sectoral programs were using PSI conditions instead of their own after PSI creation, as PSI financial conditions were better off. However, for statistical purposes, these operations were still computed in the respective sectoral program.

[12] Based on the direct fiscal cost calculated in Table 6, page 25, in Machado et al (2018).

Finally, to analyze whether subsidized innovation credit support is more cost-effective than other policy alternatives, the estimates discussed here are compared with those of Zucoloto et al (2017) for a tax incentive measure, the *Lei do Bem*[13]. The authors found positive and significant effects of the law on R&D expenditures of the beneficiary firms, but cost-effectiveness estimates tended to be lower than the unit. Thus, the conclusion is that part of the increase in private R&D expenditure occurs only as a substitute for public spending, evidencing some degree of crowding out of the incentives granted. Thus, if the cost approximations of BNDES support from the present analysis are consistent, subsidized credit support tended to be more cost-effective than tax incentive measures.

Table 6: Cost-effectiveness ratio of BNDES innovation support through 2005-2014

	Observed **(1)**	**Counterfactual** **(2)**	**Additional** **(3)=(1)-(2)**	**Financed** **(4)**	**Estimated subsidies** **(5)**	**Cost-effectiveness ratio** **(6)=(3)/(5)**
Total Innovative Expenditure (TIE)	78,301	61,779	16,522	39,989	9,997	1.65
R&D Expenditure (RDE)	47,018	34,006	13,012	24,013	6,003	2.17

Notes: nominal values in Brazilian thousand Reais. (1) Observed Expenditure is the sample average expenditure of the firms supported in the period for each outcome. (2) Counterfactual Expenditure was obtained after discounting the estimated average effect of support (respectively 38.3% for RDE and 26.7% for TIE) on Observed Expenditure. (3) Additional Expenditure is obtained based on the difference between Observed Expenditure and Counterfactual Expenditure. (4) The amount financed is obtained based on the average of the annual values contracted by firms in innovation projects over the entire period. To calculate the portion referring to the financed R&D amounts, the ratio between RDE and TIE of 0.6 in the period was used.[14] (5) Estimated subsidies calculated based on the 25% proxy used.
Source: Pintec (IBGE) and BNDES.

5. Conclusion

This paper evaluated the effects of BNDES direct support, in the form of soft loans, on firms' innovation efforts. It contributes to the Brazilian empirical innovation literature as it is the first one to evaluate the cost-effectiveness of soft loans instruments for innovation, like BNDES' ones, allowing comparison of additionality estimates among distinct Brazilian instruments to support innovation.

Using firm-level data on innovation activities and on access to BNDES innovation loans, we constructed a panel dataset over the period 2005-2014 to estimate the effects of the intervention. We adopted a Fixed Effects approach to deal with the endogeneity problem associated to the selection of firms that receive the loans and to estimate BNDES input additionality. In addition, this analysis aimed to discuss the additionality of BNDES

[13] Lei do Bem is a tax incentive policy that allows deduction of up to 100% in Income Tax and Social Contribution on Net Income with R&D activities, as well as allowing accelerated amortization and depreciation, among other measures aimed at relieving the company that aims to innovate (Zucoloto et al, 2017).
[14] As mentioned above, innovation projects financed do not only contain R&D expenditures, but also equipment, software and other innovation expenditures, as BNDES addopts a broad concept of innovation.

innovation financing in the same period. Such estimates tend to be increasingly relevant to support policy decisions and priorities, towards a more effective BNDES role.

Our findings showed evidence of positive and significant BNDES effects on firms' R&D and total innovation expenditures. Based on the FE estimates, we obtained estimates of a substantial increase in firms' R&D expenditures of almost 40%. Also, the cost-effectiveness estimates indicated a complementary relation between private and public sources of financing innovation expenditures at the firm-level.

The obtained evidence corroborates with the theoretical view of the existence of restrictions on the private financing of innovative activities, discussed in Hall (2002). These restrictions tend to be especially relevant in developing countries, where capital markets are less developed. Then, although it is unclear which incentive mechanisms present in the loans instruments evaluated here were more relevant for unlocking innovative spending decisions, it seems that interest rates subsidies may be the main driver of the results in this context.

Future research agenda will focus on estimating the effects on output additionality, incorporating other firms' dimensions, related to innovation performance, productivity and growth. We also intend to employ alternative approaches for estimating BNDES loans effects to evaluate the robustness of our results.

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