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## PUBLIC SUPPORT TO FIRM-LEVEL INNOVATION: AN EVALUATION OF THE FONTEC PROGRAM

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**ABSTRACT**

Latin-American Governments have frequently adopted Technology Development Funds (TDF) to financially support innovation activities of firms. In this paper, we analyzed the effectiveness of a Chilean TDF, the FONTEC program. We found that FONTEC's subsides partially crowded-out private investments in innovation and they more effectively promoted technological upgrades and process innovations, rather than radical product innovations. In the empirical analysis, we considered four levels of potential impact: input additionality, behavioral additionality, innovative output, and performances. In terms of input additionality, although FONTEC increased the overall R&D budget of the firms, it did not stimulate additional private investment in innovation activities. In terms of behavioral additionality, FONTEC effectively promoted process innovation and induced changes in the innovation strategy of the firms. In terms of innovative outputs, FONTEC did not significantly foster patenting activities and had no significant impact on the creation and adoption of new products. In terms of performances, although FONTEC increased the sales, employment and export, it did not significantly foster productivity. In the absence of randomized experiments, we estimated these impacts through a quasi-experimental approach that combines difference-in-difference and propensity score matching techniques.

## INTRODUCTION

Since the beginning of the 1990s, several Latin American countries have witnessed an impressive growth of public programs aimed at enhancing firm-level innovation and modernization. The justification for these programs was that the market had failed to provide the incentives needed to reach an optimal level of private investment in innovation activities. Therefore, Latin American firms failed to adopt modern technologies and business practices that would have helped them to improve their productivity and competitiveness.

In this context, several Latin American countries have introduced various types of subsidies to stimulate innovation activities and to strengthen the linkages among firms and other agents in the National System of Innovation (NSI). These subsidies started in Chile in 1993 and they have been replicated in Argentina, Colombia, Mexico, Panama, Peru, Paraguay and Uruguay.

Although more than a decade has passed since the first subsidies of this kind were introduced, very little credible and convincing empirical evidence exists regarding their impacts and effectiveness. The aim of this paper is to address this gap by using quasi-experimental econometric techniques to evaluate the impact of the Chilean National Fund for Technological and Productive Development, henceforth referred to it as FONTEC. For this purpose, the paper considers four levels of potential impact: input additionality, behavioral additionality, innovative output, and performances.

We found evidence of a partial crowding-out effects between the subsidies granted by FONTEC and the resources of the beneficiary firms, which means that the average firm-level investment in innovation did not increased by the full amount of the average subsidy. We found a positive impact of the program on process innovation and on the firms' capabilities of interacting with external sources of knowledge and financing. However, we did not find evidence of any significant impact on the creation and adoption of new products. Finally, despite finding a positive impact on employment, sales and exports, we could not clearly support a significant result in terms of productivity.

To evaluate the FONTEC impact, we used a survey of beneficiary and control firms implemented by the Chilean *Corporación de Fomento* (CORFO) to collect information on innovation efforts, behaviors and performances before and after the participation in FONTEC.[1] The questionnaire of the survey followed the guidelines of the OSLO Manual (OECD, 2005), allowing the collection of both

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[1] This data collection was part of part of an evaluation project carried out by the University of Chile and coordinated by José Miguel Benavente (see University of Chile, 2004).

quantitative information regarding economic results and qualitative information regarding strategic behaviors and linkages. We adopted difference-in-difference and propensity score matching methods to estimate the program's impacts.

Following this introduction, this paper is organized as follows: Section I discusses the FONTEC antecedents and theoretical rationale. Section II discusses the research hypothesis, describes the dataset used for the evaluation and discusses the econometric strategy. Section III summarizes the empirical results and Section IV concludes.

# I.   THE FONTEC PROGRAM: ANTECEDENTS AND RATIONALE

## A.   THE ANTECEDENTS OF FONTEC

The recent evolution of the Chilean NSI has been remarkable. Indeed, during the last 15 years, Chile has performed above the Latin American average in terms of Science and Technology (S&T) indicators and its NSI has been among the most dynamic of the region. However, the participation of the private sector in the national innovation efforts is still quite limited. In order to deal with this problem, the Chilean authorities have set up a rather complex system of interventions, often supported by Multilaterals Organizations, such as the Inter-American Development Bank (IDB).[2]

In this context, the FONTEC program provides financing for innovation projects carried out by private firms. FONTEC was established in 1991 and, during its first ten years, supported more than 1,700 innovation projects whose value amounted to US$ 250 million. Overall, the FONTEC matching-grants system subsidized 38% of this value. During the same period, 6,000 firms participated in FONTEC, 85% of which were small and medium-size enterprises (SMEs). In terms of sectors, 41% of funds were allocated to firms in the manufacturing sector, 29% to firms in the agricultural and fishery sectors and 8% to Information and Communications Technologies (ICT) activities.

The co-funding requirement is certainly one of the most important characteristics of the program: while in 1992 the resources contributed by firms amounted to around 43% of the project portfolio, between 1997 and 2001, the share of private investment reached around 65% of the project portfolio.

FONTEC's original design identified the following objectives: "(i) to promote Research and Development (R&D), scientific technical services and other activities that contribute to technological development and thereby help enhance the ability of private business to compete and increase their output; (ii) to expand the national technology supply and use of technology either generated or adapted in Chile; and (iii) to promote interaction and cooperation between the country's public research organizations and its businesses encouraging them to undertake joint projects" (IDB 1991).

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[2] The IDB actively supported the technology policy of Chile since its return to democracy. In particular, the IDB provided financial support to two Chilean National Innovation Programs: the Science and Technology Program (1992-1995) and the Technology Development and Innovation Program (2001-2006). In the context of the former, the IDB participated in the design and implementation of FONTEC.

To achieve these objectives, FONTEC operates five financing lines:

Line 1 - Technological innovation: it finances projects aimed at developing new products and improving production processes. It covers the development of prototypes and market testing. The FONTEC subsidy cannot exceed 50% of total costs.

Line 2 - Technological infrastructure: it finances investment in physical infrastructure, installation, equipment and also the training of firm staff involved in the development of this infrastructure. The co-financing limit ranges between 20% and 30%, depending on whether the investment is submitted by a single firm or a group of firms.

Line 3 - Group transfer: it supports projects submitted by a group of at least five firms and it covers the cost of technological missions abroad, training and technical assistance held by highly specialized international experts. The co-financing limit is fixed at 45% for technological missions and 50% for specialized consultants. In any case the amount of funds granted by FONTEC cannot be higher than US$100,000.

Line 4 - Technology transfer organizations: it finances projects submitted by groups of at least five firms with the aim of setting up a technology transfer centre to study, develop, diffuse and adapt technology. The maximum subsidy is equal to 50% of the investment and cannot be higher than US$400,000.

Line 5 - Pre-investment studies: it supports evaluations and studies of potential technological investment. The maximum financing cannot exceed 50% of the overall cost or US$15,000.

The focus of this evaluation is on the impacts of Line 1, which accounts for almost 80% of total public funding. Table 1 summarizes the number of projects, recipients and funding for each of the 5 financing lines.

Table 1 – Projects, Beneficiaries and Funds by Line of Financing 1991-2003

|  | n. projects | n. firms* | Total value[+] | FONTEC[+] | Line / Total | Firms[+] |
|---|---|---|---|---|---|---|
| Line 1 | 1,784 | 1,315 | 197,199,735 | 74,588,150 | 79.39% | 77,851 |
| Line 2 | 41 | 51 | 11,583,772 | 2,836,488 | 3.02% | 5,554 |
| Individual | 36 | -- | 7,644,817 | 1,965,540 | 2.09% | 3,606 |
| Group | 5 | -- | 3,938,955 | 869,373 | 0.93% | 1,948 |
| Line 3 | 508 | 4,067 | 24,980,313 | 10,416,732 | 11.09% | 9,247 |
| Missions | 460 | -- | 22,332,819 | 9,454,437 | 10.06% | 8,178 |
| Consultants | 48 | -- | 2,647,494 | 963,871 | 1.03% | 1,069 |
| Line 4 | 10 | 132 | 4,672,882 | 2,247,456 | 2.39% | 1,540 |

|  | n. projects | n. firms* | Total value[+] | FONTEC[+] | Line / Total | Firms[+] |
|---|---|---|---|---|---|---|
| Line 5 | 69 | 41 | 1,502,504 | 636,281 | 0.68% | 549 |
| Special Calls | 47 | -- | 8,931,553 | 3,230,226 | 3.44% | 3,620 |
| Education ICT | 21 | -- | 3,994,078 | 1,289,886 | 1.37% | 1,717 |
| Clean Production | 26 | -- | 4,937,474 | 1,940,341 | 2.07% | 1,903 |
| Total | 2,459 | 5,606 | 248,870,759 | 93,955,334 | 100.00% | 98,362 |

\* Information available up to 2001
[+] USD

*Source: Authors' elaboration on the basis of CORFO and Dini and Stumpo (2002).*

The FONTEC operational structure includes an executive director and three main departments: (i) the Operations Department, which manages the selection and evaluation process, contract negotiations with clients, and the follow-up of project execution; (ii) the Legal Department, which is mainly involved with drafting of contracts and assessment of guarantees; (iii) the Administration Department which handles the disbursements and other administrative matters. FONTEC has around 25 staff, most of whom are engineers. In addition to this, FONTEC is also supported by some external organizations under contract. Applications for financing are evaluated by a committee composed of two representatives from CORFO, two from the Ministry of Economy, one from the Ministry of Treasury and three representatives from private sector associations.

## B.     THE RATIONALE OF FONTEC

Before proceeding with the evaluation, it is important to discuss the rationale for a public program such as FONTEC. The economic literature has extensively documented many market failures that lead the private sector to under-invest in innovation.[3] Market failures arise from four main sets of reasons: (i) incomplete appropriability of the innovation rents; (ii) asymmetric information and moral hazard that limit access to external funding; (iii) the intangible nature of assets accumulated through R&D investments that make them ineligible as guarantee for commercial loans and (iv) network externalities.

As first described by Nelson (1959) and Arrow (1962), the returns to investments in R&D cannot be fully appropriated by the investor, given that knowledge is a non-rival good and that the possibilities for exclusion are limited[4]. Therefore, the

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[3] See, for example, Levin et al. (1987), Mansfield et al. (1981) and Martin and Scott (2000).
[4] Knowledge goods cannot practically be withheld from one individual consumer without withholding them from all (the 'non-excludability criterion') and for which the marginal cost of an additional person consuming them, once they have been produced, is zero (the 'non-rivalrous consumption' criterion).

private returns associated with such investments are usually much lower than the social ones.

Financial market failures have also been a key justification for R&D public funding. Credit and liquidity constraints are probably the most diffused market failures that hamper the development of innovation projects. The high asymmetry of information between the lender and the borrower on technical contents of the innovation projects seriously limits the possibility to obtain funding from financial intermediaries. In such a context, a potential solution is the provision of low-cost public financial resources either through subsidies or soft credit lines. Some econometric evidence shows that small and new R&D intensive firms often experience the most significant impacts of R&D projects, and they are precisely the most affected by financial constraints.[5] However, the argument may not be so relevant for large and established firms, which are less likely to be financially constrained.

Some evolutionary scholars complemented this market-failure approach stating that the public intervention should also address the dynamic, collective, uncertain and discontinuous nature of the innovation process.[6] This implies that public intervention is not only justified in the conventional cases of the market failure, but also in cases of non-market failure, such as the lack of linkages within the National Innovation System (NSI) and the deficient absorption capacity of the agents within the system.

Finally, the literature has devoted an increasing level of attention to the potential social benefits of networking and interactive learning. Firms could benefit from the connections with each other, not only because they lack resources, as the resource-based view states, but also because of the need to explore and benefit from other firms' knowledge bases.[7]

Lines 1, 2 and 5 of FONTEC clearly deal with financial constraints and, in fact, were originally designed as targeted credit lines. Line 1, in particular, originally adopted a shared-risks-and-benefits logic: if the project was successful then the loan would have been fully repaid by the firm, with interest and with a surcharge on the loan amount, depending on what results the project evaluation said could have been expected. If the project failed to produce the expected results, the firm

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[5] See for example Klette and Moen (1999), Hall (2002) and Duguet (2004).
[6] See Nelson and Winter (1982), Dosi et al. (1988), Dosi and Nelson (1994), Metcalfe (1994), Cimoli and Dosi (1995) and Teubal (1998).
[7] According to the "network of learning" (Powell et al. 1996) and to the "interactive learning" approaches (Lundvall 1988 and 1992, Morgan 1996), networks facilitate organizational learning and act as a locus of innovation. Thus, "organizational learning is both a function of access to new knowledge and the capabilities of utilizing and building on such knowledge" (Powell et al. 1996: 118).

would have been entitled to a subsidy equivalent to 50% of FONTEC's contribution, in other words, up to 40% of the total value of the project.

Between 1993 and 1994, the Chilean Government modified both Line 1 and Line 2, transforming the loans into subsidies and dropping the shared-risks-and-benefits approach.[8] Thereafter, both lines 1 and 2 adopted a matching-grant mechanism, which allowed for reducing the administrative cost of the provision of public funds and mobilizing private resources for innovation. However, the substitution of credit with subsidies and the removal of the shared-risks-and-benefits component could have increased the risk of opportunistic behavior by firms and adverse selection of beneficiaries.[9]

Lines 3 and 4 of FONTEC aim at taking advantage of the benefits of joint ventures and alliances in developing innovations. The rationale of this type of intervention is twofold: first, it aims at reducing the typical duplication problem of the private investment in R&D, problem that often emerges when cooperation between firms is not allowed or supported. Second, research collaboration might allow for a better appropriation of innovation rents, leading to a private investment closer to its social optimum. A potential problem with research cooperation is that collaboration could degenerate into collusion and, thus, reduces the social welfare by increasing innovation prices above marginal costs. In order to solve this dilemma, the literature has proposed solutions such as R&D cooperatives and Research Joint Ventures (RJVs), where firms are allowed and encouraged to coordinate their R&D investment during a first stage and then they are forced to engage in Cournot or Bertrand competition during a second stage.[10]

Additionally, Line 4 also aims at supporting the generation of public or semi-public goods needed to carry out innovation projects. In this regard, the program deals with the constraints that may arise due to the lack of technical capabilities or infrastructure that have the nature of public or semi-public goods, such as highly specialized laboratories and equipment.

The specific mechanism of delivering funds reveals other important features of the FONTEC rationale. As we have already mentioned, since 1993 FONTEC has been funding its beneficiaries through matching-grants awarded on the basis of a project selection mechanism. Subsidies could have been awarded through

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[8] Two reasons were the basis of this decision: first, CORFO, i.e. the agency that manage FONTEC, was going through a deep reform process that implied the closing of all the first tier credit line; secondly, the use of the credit, even a targeted credit, generated many difficulties in differentiating between innovation and investment projects.

[9] A more detailed discussion about the potential opportunistic behavior of beneficiaries or crowding-out effect is provided in the next section.

[10] On this specific topic see d'Aspremont and Jacquemin 1988; Martin and Scott 2000; Martin 2006.

alternative mechanisms, such as fiscal exemptions, which do not require the selection of projects by a public agent and rest on the assumption that firms are in the best position to select which projects should be financed.

The direct selection of innovation projects by a specialized public agent has three justifications. First, the public agent acts as a screener, conveying the technical knowledge and know-how that the financial markets lack or are not willing to develop. This process could contribute to reducing the asymmetry of information between the financial sector and the innovative firm and allow for filling the knowledge gap between borrower and lender. Second, the public agent has the possibility and the authority of performing a monitoring or supervisory role that diminishes the risk of moral hazard by the firm. Third, the public agent aims at selecting those projects that being profitable for the firm have the highest social returns. Under these assumptions, the agency selects projects that hardly would have been financed otherwise, either due to asymmetries of information or to lack of private returns.

Figure 1 summarizes the rationale of FONTEC, defining the relationship among failures that the program aims to address, the instruments for correcting these failures and the expected results. The figure clearly shows that FONTEC is a complex program aimed at tackling different constraints that could hamper innovation activities.

**Figure 1 – The FONTEC Rationale**
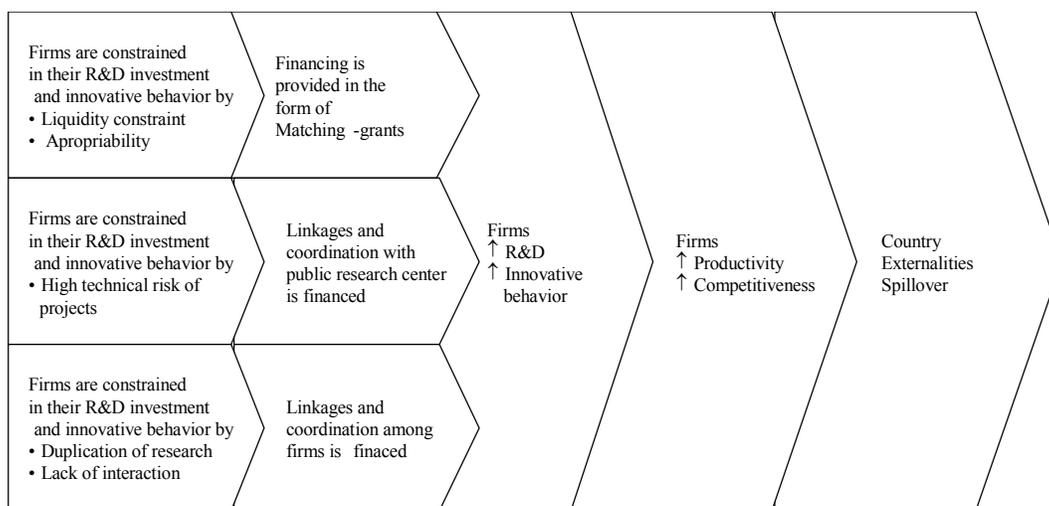
## II.   RESEARCH HYPOTHESIS, DATA AND METHODOLOGY

### A.   RESEARCH HYPOTHESIS: THE FONTEC EXPECTED IMPACTS

In order to assess the impact of FONTEC, we followed the causality chain suggested by Pakes and Griliches (1984). Following this approach, we evaluated the impact of FONTEC on four levels of outcomes: (i) input additionality, (ii) behavioral additionality, (iii) innovative output, and (iv) performances. Therefore, our basic evaluation questions are the following:

(i)   What was the impact of FONTEC on the investment in R&D of the beneficiary firms? We evaluated the program impact on the beneficiaries' own financial resources devoted to R&D and innovation activities, as a test for the potential crowding-out effect of the public financing.

(ii)   What was the impact of FONTEC on the innovation strategy of the beneficiary firms and on their insertion in the NSI? We evaluated the program effectiveness in inducing changes in the innovative behavior of the beneficiaries and on allowing them to be more connected to the NSI.

(iii)   What was the impact of FONTEC on the innovation output of the beneficiary firms? We evaluated the effectiveness of the public financing in inducing more product and process innovations and patents.

(iv)   What was the impact of FONTEC on beneficiaries' economic performance? If a significant product or process innovation occurred, firms should grow, increasing their market shares, productivity and international competitiveness.

Figure 2 outlines the FONTEC expected outcomes over time. While outcome (i) is expected to occur in the short-run, outcomes (ii) and (iii) are more likely to take place in the medium-run and outcome (iv) is expected to be achieved in the long-run.

**Figure 2: Evaluation Model**
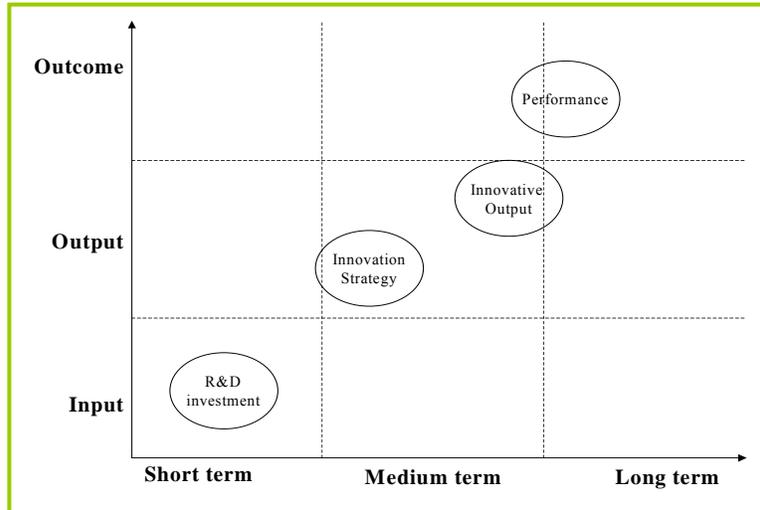


**B.    DESCRIPTION OF THE DATA**

Figure 3 summarizes the linkages among research questions, the indicators needed for the empirical analysis and the source of information. A major problem was the lack of an evaluation design that included a data collection system for tracking outcomes of interest for both beneficiary and non-beneficiary firms. CORFO overcame this problem by using administrative records and implementing a recall survey.

**Figure 3 – FONTEC Research Questions, Indicators and Data Sources**
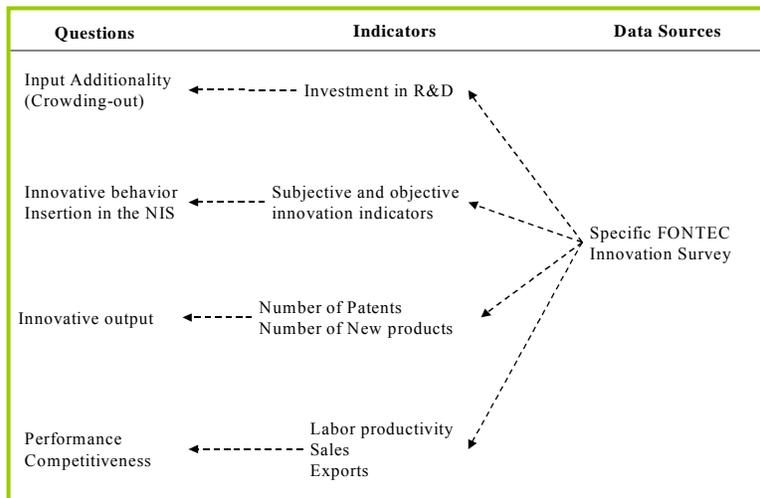
The survey, collected by the University of Chile, focused on firms funded by Line 1 between 1999 and 2002. The total sample included a group of 319 treated firms and an equal sample of non-treated firms. The control sample was generated by the Tax Authority with the aim of replicating the geographical and sectoral distributions of participant firms. At the end of the survey, 219 beneficiaries and 220 non-beneficiaries were successfully interviewed; this yielded an overall response rate of 70%[11]. However, as shown by Table 2, only a sub-sample of the interviewed firms provided all the required information including data about firm's economic and financial performances.

**Table 2 – FONTEC Survey**

|  | Total Survey | Innovation Questions | Economic and Financial Questions |
|---|---|---|---|
| FONTEC | 219 | 219 (100%) | 85 (38%) |
| Control Group | 220 | 220 (100%) | 71 (32%) |
| Total | 439 | 439 (100%) | 156 (35%) |

*Notes*: Figures in column 3 are after correcting by outliers and inconsistent observations.

The questionnaire of the survey included six sections:

a. Identification: it includes information about the firm's legal organization, location and sector.

b. Economic and financial performances: it includes data on sales, employment, salaries, investment in R&D, fixed asset investments and exports in the period between 1998-2002.

c. Business management and innovation: it includes a series of questions about organization changes and innovation outputs developed by the firm in the period between 1998-2002.

d. Relationship with the FONTEC program (only beneficiaries): it includes several questions asking for the motivation for participating in the program and a "customer-satisfaction" evaluation of program services, among other public perceptions.

e. Characteristics of the project developed through the program (only beneficiaries).

f. Value attributed to the project undertaken with FONTEC (only beneficiaries).

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[11] This response rate is acceptable for voluntary surveys such as this one. According to the Eurostat Community Innovation Survey (CIS) response rates vary between 20% (Germany) to 95% (Norway).

In this evaluation, we focused mainly on results of sections (a) to (c) and partially on (d). In several cases, these sections included questions that asked for qualitative answer using ordinal measurement scales.[12] Also, these sections included several multi-level questions. This produced a vast set of information that had to be aggregated in order to simplify the dimensions of the analysis.

When we dealt with the analysis of behavioral changes that occurred within the firms, we adopted some indicators calculated by combining two types of variables collected in the survey: first firms, both treated and control, were asked if they had introduced some changes in terms of production processes, management of human resources and internal/external organization of the firm. Then, they were asked to rank the relevance of the changes introduced according to the potential impact on competitiveness, as a way to give a metric to the different changes.

In order to make use of this information, we developed an indicator that, using the relevance rating, transforms a potential dummy variable, i.e. whether the specific changes occurred or not, into continuous variables that range between 0 and 1:

$$ GE_{kj} = \frac{1}{4n_{kj}} \sum_{i=1}^{n_{kj}} GRADE_{ij} \ (1) $$

where GE stands for Grade Evaluation, $GRADE_{ij}$ is the score (between 0 and 4) attributed by firm $j$ to the potential change $i$ and $n_{kj}$ is the number of potential changes included in question $k$ of the questionnaire that are applicable to firm $j$.[13] The index ranges from 0 when the firm reported a zero evaluation to all the potential changes, and 1 when the firm reported an evaluation of 4 to all the potential changes.

## C.    ESTIMATION STRATEGY

Our estimation strategy was based on comparing treated and non-treated firms. Under this framework, the first step was to identify comparable firms in the two groups. The survey sampling strategy was designed to have comparable firms across a limited set of standard administrative variables, such as productive

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[12] Several options are available for questions that use subjective scales. One is to use a Likert scale with a neutral centre-point: "no opinion" can form the centre of a scale ranging from "strongly disagree" to "strongly agree". Another option is to use a unidirectional scale that ranges from "not important" to "crucially important". Most innovation surveys use unidirectional subjective scales. We apply unidirectional scales in this paper as well (for further details on measurement issues using ordinal scales see Arundel et. al 1998).

[13] For example, the area "process innovation" includes 13 potential changes, of which just $n$ may be applicable to firm $j$). This means that we exclude changes that are NA.

sector, geographical location and size. However, after the collection of the survey, this original sample resulted mismatched because of the distribution of the responses. Also, the survey provided much additional information on the characteristics of the firms that could be used in the matching procedure. Therefore, in order to reduce any potential bias, we re-matched treatment and control samples after the survey collection.

The Propensity Score Matching (PSM) is a procedure that allows for generating sub samples of firms that are similar in several dimensions based on information obtained directly from the fieldwork and dated before their participation in the program. The propensity score is defined by Rosenbaum and Rubin (1983) as the conditional probability of receiving a treatment given pretreatment characteristics:

$$p(X) \equiv P(D = 1 | X) = E(D | X) \quad (2)$$

where $D=\{0,1\}$ is the indicator of exposure to treatment and X is a multidimensional vector of pretreatment characteristics. Rosenbaum and Rubin (1983) show that if the exposure to treatment is random within cells defined by X, it is also random within cells defined by the values of the one-dimensional variable $p(X)$. As a result the average effect of the treatment on the treated (ATT) can be estimated as follows:

$$\tau = E[E(Y_1 | D = 1, p(X)) - E(Y_o | D = 0, p(X)) | D = 1] \quad (3)$$

where the outer expectation is over the distribution of $(p(X)/D=1)$ and $Y_1$ and $Y_0$ are the potential outcomes in the two counterfactual situations of treatment and no treatment. Equation (3) provides for an unbiased estimator of impacts under the assumptions that observations with the same propensity score have the same distribution of observable characteristics independently of treatment status (the balancing of observables property) and that assignment to treatment is unconfounded given the propensity score.[14]

The estimated propensity score can be used to match each treated firm with one or more comparable control firms. In general, the form of the matching estimator (the empirical counterpart of (3)) is given by:

$$\hat{\alpha} = \sum_{i \in T} \left\{ Y_{i1} - \sum_{j \in C} W_{ij} Y_{j0} \right\} \cdot w_i \quad (4)$$

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[14] See Becker and Ichino (2002) for further details.

where *T* and *C* represent the treatment and comparison groups respectively, $W_{ij}$ is the weight placed on comparison observation *j* for firm *i* and $w_i$ accounts for the re-weighting that reconstructs the outcome distribution for the treated sample.

In order to estimate the propensity score, we performed a standard Logit Model where the binary dependant variable reflects the firm's participation in the program. Pre-program participation levels of sales, productive experience, and productive sector, among others were used as a vector of independent variables. Once done, we predicted the propensity score for each firm and a comparison between both propensity score distributions is reported in order to analyze differences in their chances to participate in the program. This was done in order to obtain a sub sample of firms that are comparable just before the program started.

**Table 3 – Participation Model**

| COEFFICIENT | FONTEC | MARGINAL EFFECTS |
|---|---|---|
| Experience | -0.0933*** | -0.0231** |
| | (0.036) | (0.0089) |
| Experience squared | 0.00105** | 0.0002** |
| | (0.00047) | (0.0001) |
| Productive sector [1] | -1.507*** | -0.3731*** |
| | (0.38) | (0.0945) |
| Sales 1998 | -0.0000 | -2.50e-12 |
| | (0.000) | (2.19e-12) |
| Constant | 2.121*** | |
| | (0.57) | |
| Observations | 156 | 156 |
| R-squared | 0.125 | 0.125 |

*Notes:* Standard errors in parentheses. * significant at 10% level; ** significant at 5% level; *** significant at 1% level. [1]The sample was split into two economic sectors: traditional vs. advanced manufacturing. The base category is advanced manufacturing (which includes the chemical, machinery and equipment, transport and electronic branches).

Table 3 shows the results of estimating the participation model. The results suggest that program's participation was higher among relatively new and manufacturing firms. Also, firms from advanced manufacturing sectors showed a higher probability of participation.
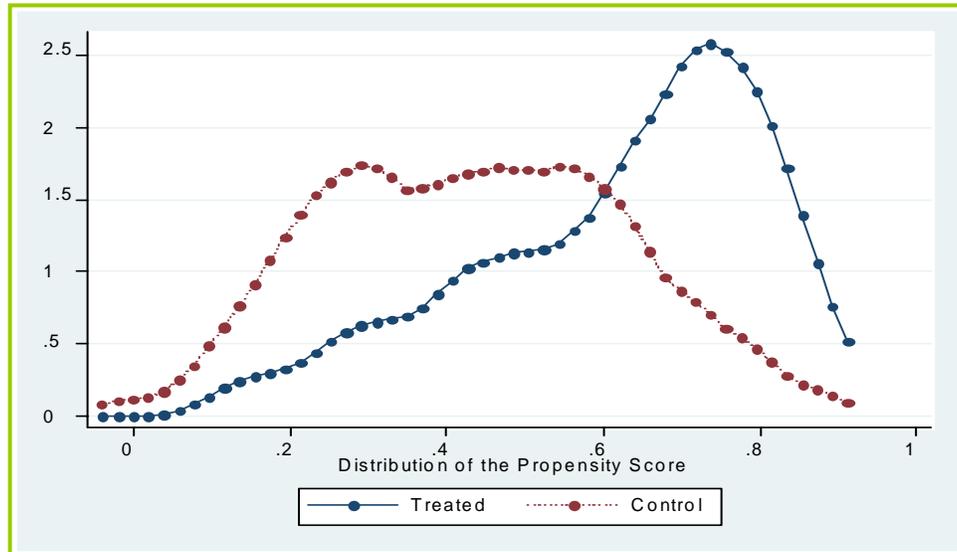
**Figure 4 – Propensity Score Common Support**



Figure 4 plots the propensity score distributions across both groups of firms. The results show that despite the fact that both distributions are not quite similar, the common support is wide. That is, every firm from each group had a positive chance - some of them higher than others, to participate in the program. Secondly, treated firms had a larger probability to participate in the program compared to those belonging to the control group. This result suggests that a discretionary or selective process from the program's administration may have been in place. However, the evidence is very weak since the common support covers most of the range of the dependent variable. Finally, these mismatches may respond to the high level of volatility observed in the independent variables mostly related to the low number of observations included in both samples.

We estimated the impact of the program in double difference, i.e. before – after and treated – non-treated, on a group of beneficiary and non-beneficiary firms matched on the basis of their ex-ante participation probability, that is the propensity score. This procedure, know as Difference-in-Difference (DID) with PSM, allows for controlling for two potential sources of bias: the PSM controls for the potential selection on observables and the difference-in-differences estimation removes any non-observable time-invariant differences among the individual firms of the two groups.[15]

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[15] See Blundell & Costa-Dias (2002).

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## A.      INPUT ADDITIONALITY: TESTING FOR CROWDING-IN AND CROWDING-OUT EFFECTS

In this section, we analyze to what extent the resources provided by FONTEC to the treated firms had been additional to other sources of financing, either internal or external. This is one of the most explored impacts of this kind of program and it has been defined by the literature as the crowding-in/out effect (David and Hall, 2000). Funds for R&D projects carried out at firm level may come from many sources: internal sources, external sources either private, from shareholder or financial intermediation, or public.

We addressed the relationships between the different sources of funds in order identify complementary or substitution effects between public and private sources of funds. That is, we could not simply assume that a given increase in public funds to the firm will lead immediately to a proportional increase in the overall research budget:[16] we had to consider the potential presence of a crowding-in, or crowding-out, phenomenon.

The subsidies given by a public program to an individual firm to carry out some specific research project have the potential to affect a whole set or part of a portfolio of innovation activities carried out by the firm. From the firm's point of view, therefore, receiving a subsidy may turn an unprofitable project into a profitable one. Alternatively, it may speed-up the completion of a project already underway. If the subsidized project involves the setting up or upgrading of research facilities, this will reduce the fixed costs of other current and future research projects, increasing their probability of being completed or undertaken[17]. Also, the learning and know-how gained from the project being supported can spill over to other current and future research projects, thereby enhancing their prospects for success. In all these ways, a research subsidy may stimulate current and future innovation projects. If these hypotheses are true, we can expect an additional effect, or crowding-in, from FONTEC on private R&D funding.

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[16] Lach (2002) suggests that for this to occur two, very unrealistic, conditions are needed: first, that the supported project could not be implemented without the subsidy and, second, that receiving the subsidy does not affect the portfolio of remaining research project currently underway. If the first condition is true but the second condition does not hold we can experiment either crowding-in or crowding-out effects.

[17] Public funding to firms does not necessarily mean the funding of all sorts of research projects; there is a lot of infrastructure funding, such as in several of the FONTEC lines. The presence of this sort of funding clearly reduces the possibility of the crowding-out effects and increases the margins for complementary effects.

Another reason for crowding-in can be found in the signaling effect that the subsidy might have of the quality of the research project, or the research team. This might allow for reducing information asymmetries and increasing the external supply of private funding for the project[18].

However, there is also empirical evidence suggesting that some research projects can be carried out anyway, even in the absence of government funding. There are several external sources of funds for research proposals including other public programs. This possibility of substitution can be increased by administrators who are often under pressure to avoid the appearance of 'wasting' public funds and who may tend to fund projects with a higher success probability and with clearly identifiable results. These are projects that could have been financed by other sources of funds, suggesting that the public funds can in fact be superfluous. Additionally, the degree of substitution might be related to the significance of the liquidity constraints faced by the firms. If the supply of external funds faced by the firms is relatively elastic, public funding will reduce the costs of external funds and some of these funds could be withdrawn from the market. This does not occur if the supply of external funds is inelastic.

Another reason for substitution is that a project enhanced by a subsidy might have an effect on the price of inelastically supplied research inputs. If the subsidy turns an unattractive project into an attractive one, but there are input constraints, typically human capital, the firm may decide to discontinue what previously was an attractive project, which might have been funded by other sources of funds. The commitment to undertake the subsidized project may crowd-out other non-subsidized projects, and their accompanying resources. The time dimension might be important as well. Public resources can be used to fund the riskier component of the innovation projects, i.e. the basic research, and then private funds can be used to complete the development phase of the research project.

In order to investigate the effect of FONTEC on other sources of funds, we compute the change of the overall R&D budget by treated firms and we compared it to the same changes by the control group. In this particular case, we compare the performances before the participation (1998) with the average investment over the three years of participation (1999-2001) and one year after (2002). This is due to the fact that crowding in/out effects are expected to occur simultaneously or in the close proximity of subsidy disbursements. We use two specifications of the outcome variable: (i) the level of the overall R&D budget; and (ii) the R&D intensity, that is the ratio between R&D investment and the total sales.

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[18] This is one of the positive effects of the Small Business Innovation Research Program in the US (Lerner, 1999). Similar to the FONTEC the SBIR program also grants subsidies for pre-competitive small R&D projects.

<div align="center">**Table 4 – FONTEC Impact on R&D Investment**[19]</div>

| | Level[+] | % of sales |
|---|---|---|
| **Naïve** | | |
| BA | 2,955,111 | 0.91 |
| **Impact** | | |
| DID (mean) | 2,597,263 | 0.77 |
| DID with Kernel PSM (mean) | | |
|     Bandwidth 0.04 | 5,215,081* | 0.79 |
|     Bandwidth 0.08 | 4,973,204* | 0.74 |
|     Bandwidth 0.16 | 5,057,793* | 0.71 |
|     Bandwidth 0.24 | 4,994,074* | 0.74* |

*Notes:* * significant at 10% level; ** significant at 5% level; *** significant at 1% level. + Chilean Pesos. BA = Before After estimator (only treated firms); DID = Difference In Difference estimator (treated and non-treated); PSM = Difference In Difference estimator with Propensity Score Matching.

Table 4 shows that FONTEC increased the overall R&D budget of the beneficiary firms. All the estimators have the expected positive sign. The kernel estimators[20] calculated in terms of pesos invested in R&D are always statistically significant, while they are significant only in one case when calculated in terms of R&D intensity, i.e. as percentage of total sales. The magnitude of the program impact increases significantly when the performances of the treated firms are compared with those of the non-treated group using PSM.

However, when we computed the FONTEC effect on the net-private investment in R&D, we found some evidence of partial crowding-out.[21] On the basis of administrative data, we calculated that each FONTEC beneficiary received an average subsidy of Ch$25 million, which is slightly higher than the program average accumulated impact over the four years of the evaluation time frame. In fact, based on our previous estimation, this cumulated impact was around Ch$20

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[19] See the imbalance covariate tests for the Kernel matching estimates in the appendix. For this test we use a Bandwidth of 0.04. The results are similar with other Bandwidths. The results confirm that the matching producer has been successful in balancing the covariates.

[20] The simplest PSM method is the Nearest-Neighbor method where each treated unit is matched to its closest control according the propensity score. However, although all treated units find a match, it is clear that some of these matches will be very poor because for some of the treated units, the nearest neighbor may have a very different propensity score but it will contribute to the estimation of the treatment effects with the same weight as with good matches. The Kernel Matching methods offer a solution to this problem because all treated are matched with a weighted average of all control with weights that are inversely proportional to the distance between the propensity scores of the treated and controls.

[21] This is quite different from the results obtained by Benavente (2002) from the analysis of the Chilean Innovation Surveys (1995-1998), which provide some evidence of crowding-in effect of the public financing on the Chilean manufacturing firms. However, this study considers all public sources available and not only the FONTEC program.

million. Hence, we have some evidence that FONTEC crowded-out private resources for about 20% of the average subsidy.

This finding is consistent with much of the previous evidence. As pointed out by David et al. (2000), there is little evidence that R&D subsidies would lead firms to undertake projects that otherwise would not have been carried out.[22] This lack of impact could depend on a misjudgment of the real (or main) market failure that is hampering private investment in R&D. A subsidy is more likely to produce a significant increase in the firm's investment in R&D when liquidity and credit constraints are the main problems that the firm faces in undertaking such activities. Nevertheless, if the firm's main difficulties are more related to technical capabilities or risk aversion, the provision of subsidies is much less likely to produce a significant increase in R&D investments and could result into a substitution of private resources.[23]

<div align="center">

**Table 5 – Reason for Applying to FONTEC**

</div>

| | |
|---|---|
| Complementary source of financing | 50.2% |
| Fundamental source of financing (project rejected by the private sector) | 30.6% |
| Signal of the quality of the project outside the firm | 27.9% |
| Share the risk of being copied by the competitors (appropriability) | 26.5% |
| Signal of the quality of the project inside the firm | 23.3% |
| A way to get involved into the network of public support to innovation | 21.9% |

*Notes:* The percentages do not sum to 100% because the options were not exclusive.

In the case of FONTEC, a partial substitution effect could be due to a complementary and signaling function attributed to program participation. The qualitative information collected from the 219 interviewed beneficiaries provided some additional insights into the evaluation of this effect. In particular, program beneficiaries were asked to grade a set of potential reasons for applying to the program. Table 5 shows quite clearly that for the majority of the beneficiaries the program is an important complementary source of financing (50%), probably connected to being a signal of the quality of the project to other sources of financing (28%). Quite lower (30%) is the percentage of firms that ranked the impossibility of receiving financing from the private sector as a highly relevant reason for applying to the program.

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[22] More recent studies confirm the mixed evidence on the effectiveness of public subsidies in increasing private R&D: Gonzalez and Pazó (2004) show that in Spain subsidies go to firms that would have performed the project in any case. Lach (2002) finds that subsidies increase private investment in R&D only when a narrow definition of R&D is adopted. See also Sanguinetti (2005) and Binelli and Maffioli (2007).

[23] A displacement effect could occur when the resources released through the program are shifted either to other activities or to the direct benefit of company's shareholders.

In addition, the analysis of the role of the financed project within the work plan of the beneficiaries shows that some sort of underestimation of the human resources required to carry out the FONTEC project could have displaced other R&D activities originally included in the work plan of the firms.[24] Analyzing qualitative data provided by the survey, we found that the project financed by FONTEC was a strategic component of the research work program for 56% of the treated firms, while for 9% of the treated firms the project was in the portfolio but was not strategic. Only 4% of the treated firms declared that the project was not in their work plan.[25] These figures lead to two considerations: first, many beneficiaries would have undertaken the project financed by FONTEC even without the program, or at least would have sought alternative sources of financing. This does not necessarily mean that the FONTEC resources crowded-out other sources, but can at least explain the limited multiplier effect. Second, although the majority of the beneficiaries seem to have planned in advance the execution of project supported by FONTEC, when asked to identify the main difficulties faced during the execution of this project, 67% of the beneficiaries pointed out the lack of skilled labor force, confirming the hypothesis that some underestimation of the human resources had occurred.

Finally, the analysis of the FONTEC impact on investment in physical capital also supports the hypothesis that the limited impact on R&D investment was more due to an adjustment of firms' portfolio of R&D projects, rather than to a resource diversion towards non-R&D related investments. In fact, the participation in FONTEC did not have any positive impact on investment in physical capital. Actually, the treated firms underperformed the non-treated firms in terms of investment in machinery.

## B.     EVALUATION OF THE BEHAVIORAL ADDITIONALITY OF THE PROGRAM

The aim of this subsection is to complement the previous analysis at the input level by looking at the impacts of the participation in the FONTEC program on some intermediate outcomes of the innovative process. In particular, we aimed at identifying the internal dynamic that might have been put in place as a consequence of having received the FONTEC support. For this, we analyzed two

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[24] As noted by Lach (2002), the investment in R&D of a firm could be partially or totally displaced even when the beneficiaries effectively need the funds to undertake the financed project. In fact, if the firm lacks enough skilled human resources or faces other constraints that make it very costly to implement other projects together with the financed one, it can decide to dismiss some of the non-financed projects in order to fulfill the commitment with the public agency, thus reducing its overall level of R&D expenditures.

[25] The other 31% of beneficiaries didn't clearly identify weather the project was in their working plan.

aspects of a firm's innovative behavior: (a) process innovation and organizational change; and (b) access to external resources.

### 1. Process and Organizational Innovation

We measured the impact on process and organizational innovations using three indicators: (i) number of new production processes adopted by the firm; (ii) relevance of the process innovations adopted by the firm; and (iii) relevance of the changes in human resource management practices adopted by the firm.

With reference to the first indicator, the number of new production processes adopted by the firm, Table 6 shows that FONTEC had a positive and significant impact on the treated firms. Compared to the control group, the beneficiaries adopted, on average, 0.48 more process innovations.

**Table 6 – Process and Organizational Innovations**

|  | Number of new process | Relevance of the process introduced | Relevance of Training and HR innovation |
|---|---|---|---|
| **Naïve** |  |  |  |
| BA | 1.50 | 0.42 | 0.46 |
| **Impact** |  |  |  |
| DID | 0.41 | -0.07 | -0.06 |
| DID with Kernel PSM |  |  |  |
|    Bandwidth 0.04 | 0.28 | -0.03 | -0.09* |
|    Bandwidth 0.08 | 0.40 | -0.03 | -0.07* |
|    Bandwidth 0.16 | 0.46* | -0.02 | -0.06 |
|    Bandwidth 0.24 | 0.48* | -0.03 | -0.06 |

*Notes:* * significant at 10% level; ** significant at 5% level; *** significant at 1% level. BA = Before After estimator (only treated firms); DID = Difference In Difference estimator (treated and non-treated); PSM = Difference In Difference estimator with Propensity Score Matching.

With reference to the second indicator, which summarizes the firm's self-evaluation of the relevance of the changes introduced in the production process, the program did not have any significant impact. In order to explore in more detail what occurred within the firm, we also analyzed the components of this indicator: treated firms were more dynamic than the control group only in terms of internalizing new components of production processes, which is confirmed also by the fact that they outsourced less than the control group. On the other hand, treated firms were significantly less dynamic in adopting ICT, quality and safety control methods, and management systems.

The results are even more worrying when we considered changes in the management of human resources. In this case the impact of the program was negative in all of the specifications and sometime significant. The detailed

analysis of the components of this indicator confirms that the treated firms underperformed the control group in all the options and that the average scores were significantly different both regarding training activities and the adoption of incentives.

### 2. Improved Access to External Resources

One of the most explicit aims of the new Chilean S&T policy has always been the strengthening of the firm's linkages within NSI. In order to evaluate the impact of the program on this fundamental aspect of the learning process, both the treated and the control firms were asked to estimate the relevance of improvements achieved when using external sources of knowledge.

In this case, we found that the impact of the program was unambiguously positive and significant in almost all of the specifications, as Table 7 shows. Additionally, the analysis of disaggregated indices demonstrated that this positive impact was mainly due to a significant increase in the ability of treated firms to interact with public institutions and, even more importantly, with academic institutions. Conversely, the participation in FONTEC reduced the relevance of the competitors as a source of innovation.

**Table 7 – Access to External Resources**

|  | Improved Access to External Source of Knowledge | Improved Access to External Source of Financing |
|---|---|---|
| **Naïve** |  |  |
| BA | 0.43 | 0.34 |
| **Impact** |  |  |
| DID | 0.01 | 0.03 |
| DID with Kernel PSM |  |  |
| Bandwidth 0.04 | 0.05 | 0.09 |
| Bandwidth 0.08 | 0.08 | 0.12* |
| Bandwidth 0.16 | 0.10* | 0.13* |
| Bandwidth 0.24 | 0.10* | 0.13* |

*Notes:* * significant at 10% level; ** significant at 5% level; *** significant at 1% level. BA = Before After estimator (only treated firms); DID = Difference In Difference estimator (treated and non-treated); PSM = Difference In Difference estimator with Propensity Score Matching.

When we considered the improvements in accessing external sources of financing, the impact of the program was, again, significantly positive. More specifically, treated firms significantly improved their capabilities to define, budget and present innovation projects and they increased their knowledge on potential sources of external financing.

## C.     IMPACT ON INNOVATIVE OUTPUT

According to Nelson (1991) the development of a new product is probably one of the most important dynamic capabilities of the firm. In order to evaluate how the participation to the FONTEC program could have affected this capability, we compute the impacts of the program on two indicators of innovative outputs during the period under analysis: (i) the number of new products manufactured by the firm; and (ii) the number of patents registered by the firm.

Table 8 shows that the program had no positive impact on the beneficiaries' capabilities to develop product innovations. In fact, the treated firms did not introduce more new products than the control group during the period of the analysis. This poor performance is quite consistent with the results of previous evaluations (GERENS, 1996; ILADES, 1998; and University of Chile, 2004), which concluded that the program was more focused on process innovations and on the incremental improvements of existing products. Nevertheless, there is no structural reason that explains why the program should not have generated these results. In particular, Line 1 specifically aims at fostering the development of new products and financing prototypes and marketing tests.

**Table 8 – Impact on Innovative Output**

|                      | Number of New Products | Number of Patents |
|----------------------|------------------------|-------------------|
| **Naïve**            |                        |                   |
| BA                   | 3.11                   | 1.50              |
| **Impact**           |                        |                   |
| DID                  | -0.52                  | 0.41              |
| DID with Kernel PSM  |                        |                   |
| Bandwidth 0.04       | -1.45                  | 0.16              |
| Bandwidth 0.08       | -1.45                  | 0.15              |
| Bandwidth 0.16       | -1.45                  | 0.14              |
| Bandwidth 0.24       | -1.51                  | 0.14              |

*Notes:* * significant at 10% level; **  significant at 5% level; *** significant at 1% level. BA = Before After estimator (only treated firms); DID =  Difference In Difference estimator (treated and non-treated); PSM = Difference In Difference estimator with Propensity Score Matching.

Considering the number of products that have been patented by the firms, the results are slightly more encouraging as the program had a positive, although not significant, impact on the beneficiaries in almost all the specifications, as Table 8 shows. This result confirms that FONTEC was more effective in promoting incremental innovations, rather than radical innovations (Griliches 1990). Patenting implies a much more formalized research process and, therefore, is likely to be connected to a more complex innovation activity. Usually, a firm has

the incentive to apply for a patent when the innovative product is an absolute novelty, at least at the national level.

## D. IMPACT ON PERFORMANCES: SALES, EMPLOYMENT, EXPORT, AND PRODUCTIVITY

To conclude our evaluation, we analyzed the impact of the program on the productivity and international competitiveness of the firms. For this purpose we considered four indicators: (i) sales; (ii) employment; (iii) labor productivity; and (iv) exports as a percentage of sales.[26]

**Table 9 – Impact on Innovative Output**

|  | Sales | | Employment | | Productivity | % Export |
|---|---|---|---|---|---|---|
|  | Level[+] | Δ% | Level | Δ% | Δ% | |
| **Naïve** | | | | | | |
| BA | 122,500* | 63.1* | 7.40* | 21.7* | 38.7 | 1.56 |
| **Impact** | | | | | | |
| DID | 82,700 | 35.2 | 12.06* | 9.9 | 16.4 | -0.28 |
| DID with Kernel PSM | | | | | | |
| Bandwidth 0.04 | 62,200 | 41.1* | 7.73* | 3.9 | 23.7 | 2.60* |
| Bandwidth 0.08 | 47,500 | 39.6* | 7.39* | -0.7 | 24.9 | 2.72* |
| Bandwidth 0.16 | 50,000 | 40.3 | 6.93* | 2.2 | 26.2 | 2.70* |
| Bandwidth 0.24 | 59,400 | 39.6 | 7* | 3.1 | 26.0 | 2.67* |

*Notes:* + Thousand of Pesos. * significant at 10% level; ** significant at 5% level; *** significant at 1% level. BA = Before After estimator (only treated firms); DID = Difference In Difference estimator (treated and non-treated); PSM = Difference In Difference estimator with Propensity Score Matching.

We found that the impacts on sales, employment, labor productivity and export show the expected positive signs, although the average impacts on sales and labor productivity are not statistically significant. However, we also found that the productivity evolution of the non-treated firms was more the result of a significant contraction of the employment (-4.7%), rather than the result of an expansion of the output. Considering the peculiar situation of the Chilean economy in the years 2001-2002, we could conclude that the beneficiary firms performed better that the treated group, because they were able to grow both in terms of employment and sales. Along these lines, the results in terms of exports supported the hypothesis of a positive impact of the program on firms' competitiveness.

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[26] It is worth noting that in this evaluation impacts are measured for only one year after the participation in the program. As pointed out, the effects on performance are more likely to occur in the medium/long-run. Therefore, the analysis of the results included in this section should take into account this potential lag.

## IV. CONCLUSIONS

This paper shows the advantage of using quasi-experimental techniques to evaluate the impact of policy instruments aimed at supporting the investment in R&D of firms. In particular, these techniques allow to address a problem that Latin-American policy makers have ignored for too long: the attribution of the development outcomes to the public intervention.

Applying these techniques, we found evidence of a partial crowding-out effects between the subsidies granted by FONTEC and the resources of the beneficiary firms, which means that the average firm-level investment in innovation did not increase by the full amount of the average subsidy. We also showed that these poor results were more likely due to an adjustment of portfolio of R&D projects and to an underestimation of the human capital needed to perform the projects, rather than to a resource diversion towards non-R&D related investments.

We also found a positive impact of the program on process innovation and on the firms' capabilities of interacting with external sources of knowledge and financing. However, we did not find evidence of any significant impact on the creation and adoption of new products. These results confirm the finding of previous FONTEC's evaluations, which concluded that the program was more focused on process innovations and on the incremental improvements of existing products, rather than on radical innovation.

Finally, despite finding a positive impact on employment, sales and export, we could not clearly support a significant result in terms of productivity. However, as also suggested by Benavente et al. (2005), R&D activities take some time to have a productive impact, and therefore more time might be needed to obtain conclusive results in terms of productivity. Given the data available for this evaluation, we could not show conclusive evidence on long-run impacts.

This evaluation clearly shows the need for more frequent impact evaluations of public policies aimed at supporting the investment in R&D of private firms, in particular when these policies grant non-reimbursable resources. This does not imply any additional burden for program operations. This paper demonstrated that it would be enough to collect some basic economic and financial information on the relevant group of beneficiary and non-beneficiary firms in order to monitor the effectiveness of these policies. For instance, a follow up of this specific evaluation, allowing for larger time lags to analyze the same groups of treated and non-treated firms, would allow to find more conclusive evidence on those effects that are more likely to emerge in the long-run, such as the impact on patenting activities and productivity.

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**Covariate Imbalance Testing**
**(for the Kernel matching estimates with Bandwidth=0.04)**

| VARIABLE | SAMPLE | MEAN | | | % REDUCTION | T-TEST |
|---|---|---|---|---|---|---|
| | | Treated | Control | %bias | \|bias\| | |
| Experience | Unmatched | 22.7 | 30.6 | -44.2 | | -2.58** |
| | Matched | 22.7 | 20.5 | 12.0 | 72.8 | 0.78 |
| Experience squared | Unmatched | 830.8 | 1260.2 | -30.6 | | -1.79* |
| | Matched | 830.8 | 679.8 | 10.7 | 64.8 | 0.74 |
| Economic Sector | Unmatched | 0.197 | 0.500 | -66.5 | | -3.93*** |
| | Matched | 0.197 | 0.234 | -8.1 | 87.8 | -0.55 |
| Sales (1998) | Unmatched | 4.2e+09 | 1.5e+10 | -27.6 | | -1.69* |
| | Matched | 4.2e+09 | 3.2e+09 | 2.4 | 91.2 | 0.55 |
| Pseudo R2 | Unmatched | 0.164 | | | | |
| | Matched | 0.006 | | | | |
| LR Chi2 | Unmatched | 31.13*** | | | | |
| | Matched | 1.27 | | | | |

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