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Working Paper: OVE/WP-03/07
October, 2007

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Inter-American Development Bank
Washington, D.C.

Office of Evaluation and Oversight, OVE

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This paper is part of the project: "IDB's Science and Technology Programs: An Evaluation of the Technology Development Funds (TDF) and Competitive Research Grants (CRG)", by the Office of Evaluation and Oversight (OVE) of the Inter-American Development Bank (IDB).

The authors thank Roberto Iunes, Inder Ruprah, Yuri Soares, and Diego Ubfal for useful discussions. The findings and interpretations of the authors do not necessarily represent the views of the Inter-American Development Bank. The usual disclaimer applies. Correspondence to: Alessandro Maffioli, e-mail: alessandrom@iadb.org, Office of Evaluation and Oversight, Inter-American Development Bank, Stop B-719, 1300 New York Avenue, NW, Washington, D.C. 20577.

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ABSTRACT

This paper analyzes the role of National Research Funds in promoting scientific production in emerging economies. The investigation focuses on the impact of the Chilean National Science and Technology Research Fund (FONDECYT). The analysis uses data drawn from international sources of bibliometric information combined with the administrative records of the program executing unit. To measure the program's impact, we implement a Regression Discontinuity (RD) design on projects submitted for funding between 1988 and 1995. The results do not show any significant impact either in terms of publications or in terms of quality of publications in the proximity of the program threshold ranking. Although results show that the program has been partially effective in identifying the best projects in terms of expected quality, evidence suggests that the FONDECYT's lack of impact may be due to targeting problems in terms of both researchers and research projects.

JEL CODES: O30, O38

Keywords: *FONDECYT, Chile, Economics of Science, Scientific Grants, Regression-discontinuity Analysis, Policy Evaluation.*

INTRODUCTION

There is increasing recognition among academics and policy makers of the importance of scientific research in providing the foundations for both innovation and competitiveness. This has been matched by an increasing amount of public funding for such research by governments and international donors. However, there is a persistent lack of systematic evidence that these investments lead to greater scientific output and, ultimately, to better economic performance. Much of the available literature concentrates on examining how funding of basic research affects the innovative activities of firms, bypassing the whole problem of how to measure scientific outputs. This situation is mainly due to the complexity of establishing a stable causal relationship between the budgets spent on science and 'intermediate' scientific outputs. This difficulty originates from scientific research dynamic nature, which involves recursive feedbacks between inputs and outputs, and the lack of appropriate information for analysis.

The scientific process results in several research outputs that can be classified into three broadly defined categories: (1) new knowledge, (2) highly qualified human resources, and (3) new technologies. Although there are no direct measures of these types of research outputs, several proxies have been used in previous studies, among them publications, citations and numbers of PhD degrees awarded. This paper focuses on the impacts that one specific policy intervention such as a national competitive research fund has on the first type of output: the creation of new knowledge. On the basis of bibliometric data we aim to provide preliminary answers to the following research questions:

(i) Does a national competitive research fund have a 'multiplier effect' on the amount of national scientific production in an emerging country like Chile?

(ii) Does a national competitive research fund contribute to the quality of the research outputs?

The present paper concentrates on an evaluation of the Chilean National Science and Technology Research Fund (FONDECYT) and it is organized in five sections. Following this introduction, section I provides some information on the FONDECYT's institutional settings and historical evolution. Section II presents the theoretical framework needed to understand the evolution and role for FONDECYT inside the Chilean National Innovation System. Section III develops the details of the evaluation strategy, data treatment and sources and the econometric model used. Section IV discusses the main findings of the program's impact evaluation. Section V summarizes the main results, identifies potential extensions of this research, and concludes.

I. THE FONDECYT PROGRAM

A. The Chilean Innovation Policy

During the last 15 years the evolution of the Chilean National Innovation System (NIS) has shown significant progress, but also persistence of old and emergence of new problems. Chile's economic performance has been well above the Latin American average and its science and technology (S&T) development has been in line with the most dynamic economies of the region. Over time Chilean authorities have set up a complex system of interventions aimed at consolidating and improving country's S&T performance. Along this process, the role of the Inter-American Development Bank (IDB) has been critical both in terms of financial flows and in terms of technical support.

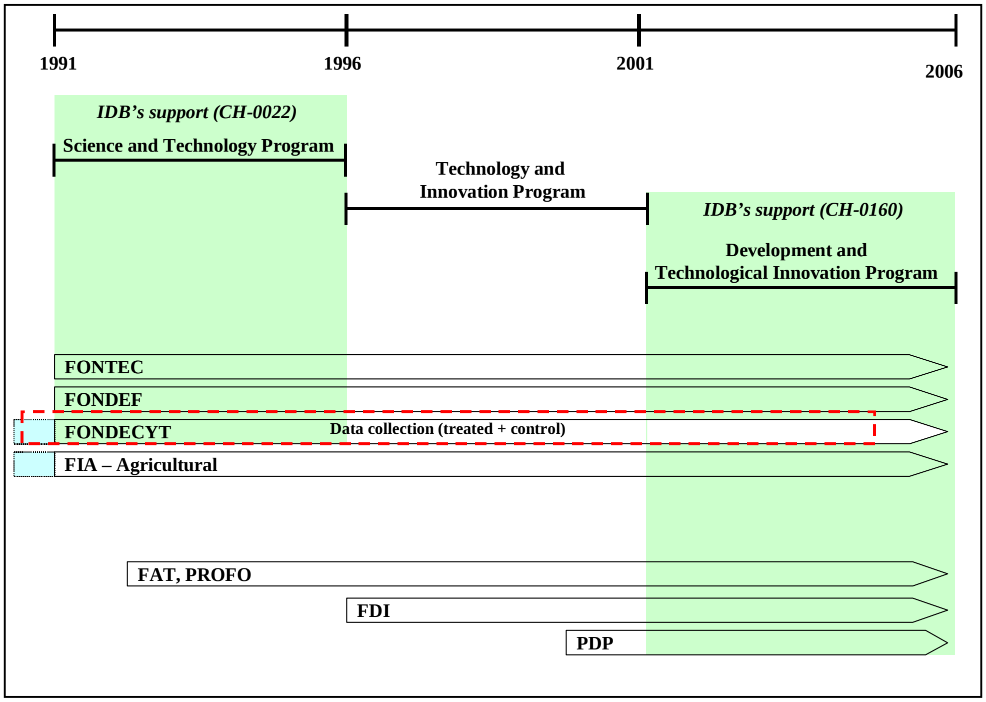
After the 1982 crisis, the Chilean economy started a phase of persistent economic growth, normally attributed to the several structural reforms carried out during the 80s and to the increasing utilization of national production capacities. However, by the beginning of the 90s, it became clear that this model was not sustainable and that new incentives to promote productivity growth were required. Based upon this diagnosis, President Aylwin's government (1990-1994), together with the IDB, developed a national innovation strategy based on the creation of series of financial instruments within the Chilean NSI.

Three consecutive National Innovation Programs (NIP) have been the pillars of this new Chilean innovation strategy: the Science and Technology Program (1992-1995), the Innovation Program (1996-2000), and the current Technology Development and Innovation Program (2001-2006). The IDB provided financial support for the first and the third NIPs.

The NIPs aimed to strengthen the Chilean NIS mainly through the creation of a set of competitive research funds, each of them focused on different aspects of the innovation strategy. Although FONDECYT was originally created in 1982, i.e. well before the first NIP, it was significantly revamped along the new Chilean innovation strategy. FONDECYT addresses universities, technical institutes and non-profit organization investigators to stimulate scientific and technological research.

Figure 1 summarizes the evolution of the different Chilean NIPs and the roles that IDB has played in each of them. It also shows the evaluation time framework used in this paper.

Figure 1 - Chile's Science and Technology Policy, IDB Interventions and Data Availability



Source: Authors' elaboration. FONTEC means National Fund for Technology and Productive Development, FONDEF means Science and Technology Development Research Fund, FIA means Agricultural Innovation Fund, FAT stands for Technical Assistance Fund, FDI means Development and Innovation Fund and PDP stands for Suppliers Development Program.

B. FONDECYT's Institutional Setting

FONDECYT aims at supporting individual and collective initiatives of national researchers, financing them on a quality and excellence basis. In particular the first Chilean NIP stated that the main FONDECYT's objective was "to maintain, strengthen and use the national capacity for high-quality research".

To select the projects to be funded, FONDECYT operates on the basis of annual competitions, open to both individual researchers and research institutions. By design, FONDECYT started as a totally neutral instrument and the quality of the research proposal was the only criterion to allocate funding.[1]

[1] The first NIP framework clearly states that: "there are so many interdependencies in knowledge and cross-fertilization among the various fields that attempts to build up a specialized capability in a given priority area are less effective unless a much broader capability for high-caliber research is maintained and practiced".

FONDECYT operates within the scope of the Chilean National Science and Technology Research Council (CONICYT) and it is funded through annual allocations from the national budget law. A National Council for Scientific and Technological Development – which includes the Ministers of Education, Planning, and Finance – is responsible for funds' allocation between basic and applied research. Additionally, this council is entrusted with negotiating additional financing from international donors. The fund's operations are managed by two Superior Councils – one for science (7 members) and one for technological development (5 members). The Superior Councils are supported by 23 study groups made up of subject specialists in the various fields of research.[2] The two Superior Councils work independently of formal linkage with CONICYT, with the exceptions of the budget preparation process and the definition of special initiatives.[3]

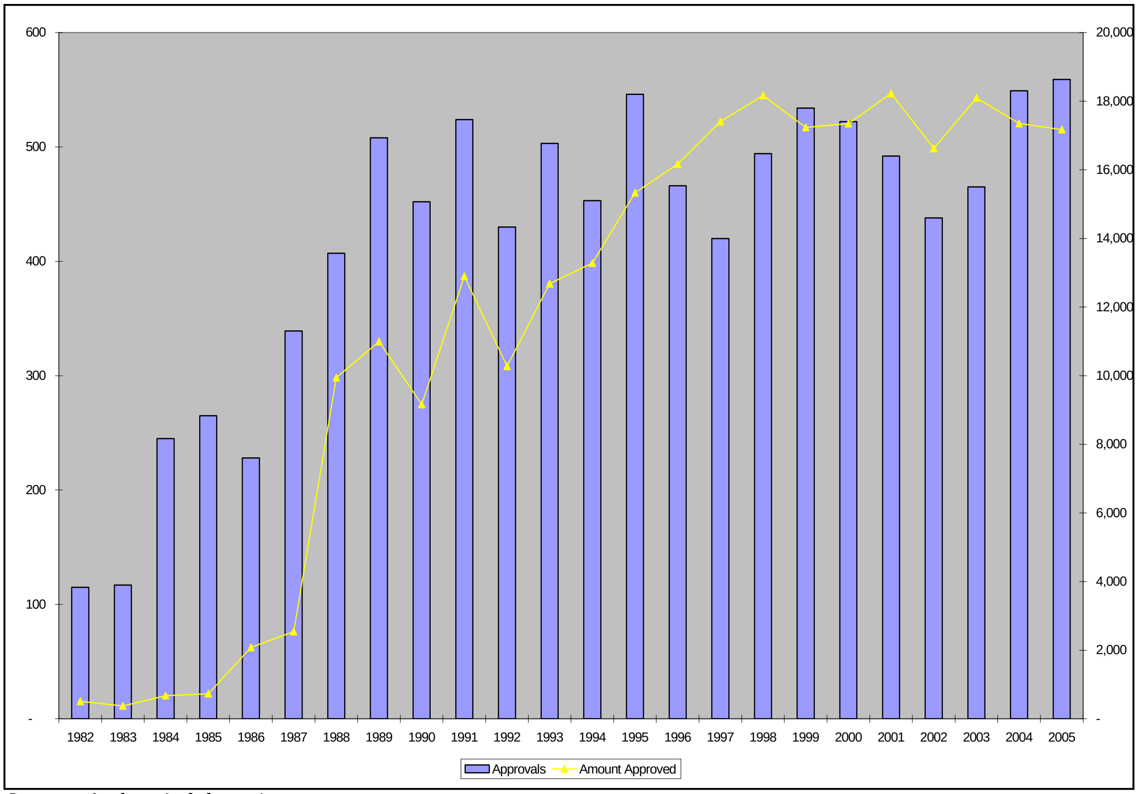
C. FONDECYT's Historic Evolution

Between 1982 and 2005 the FONDECYT program has allocated 259,710 millions of pesos (33% of the funds solicited), financing 10,071 research projects (41% of the applications received). The first stage of program's execution (1982 – 1985) was characterized by a slow growth of both the number of financed projects and resources granted per projects. Between 1986 and 1990 the average allocated funds per project increased 5 times in real terms (from CH$3.3 to CH$16.6 millions), as a consequence of two main factors: (i) the extension of maximum project duration from one to three years and (ii) the inclusion of new expenditures (such as researchers' salaries and overheads) in the eligible costs. In addition, in 1988 the program actually became a competitive fund: given the increasing number of request for financing, the program adopted a call for proposals mechanism to select the projects to be supported.

[2] Staff work is coordinated by an executive director and carried out by a FONDECYT's Administrative Unit with the support of the CONICYT Information Department and Accounting Unit.

[3] For a detailed assessment of FONDECYT institutional setting see Mullin et al. (2000).

Figure 2 – Projects Financed (left axis) and Million Chilean Pesos Granted (right axis – prices 1998)



Source: Authors' elaboration.

During the execution of the STP (1991 – 1996), the number of financed projects experienced a more volatile trend, although average financing per project in real terms kept growing (around 19% per year). It is worth noticing that in this period the program started financing both doctorate and post-doctorate grants, which accounted for 12% of the projects and 5% of the financing at the end of the period. Afterwards, between 1997 and 2005, the program reached a more stable path both in terms of projects and financing.

The analysis of the evolution of the FONDECYT in terms of scientific disciplines (Table 1) shows an increasing concentration of funding towards the science connected with the natural resources. Indeed, in 2005 the sum of Agronomics, Soil Research and Health and Animal Husbandry accounted for more than 40% of the allocated resources. In addition, it is worth noticing the relevance attributed to mathematics, as well as the huge contraction of the resources allocated to humanistic disciplines and to social sciences.

Table 1 – Evolution of the Distribution of Financing by Disciplines (ordered 2005)

DISCIPLINE	1982	1986	1991	1997	2001	2005	Δ RANKING
AGRONOMICS	0.14%	1.26%	7.79%	15.86%	9.94%	15.13%	8
MATHEMATICS	0.04%	2.36%	10.41%	9.11%	16.82%	14.00%	13
EARTH SCIENCES	0.07%	0.98%	8.97%	9.11%	12.28%	12.59%	8
ANTHROP. & ARCHAEOL.	4.50%	1.11%	5.36%	10.64%	11.51%	11.98%	2
HEALTH & ANIMAL HUSB	23.02%	1.74%	8.91%	5.14%	10.87%	9.23%	-3
ARQ.,URB.,GEOGR.& AR	0.00%	1.60%	8.53%	6.49%	4.97%	7.62%	10
EDUCATION	13.74%	0.25%	4.51%	2.09%	7.20%	4.83%	-3
SOCIOLOGY	0.00%	47.74%	2.75%	1.50%	2.04%	4.49%	9
HISTORY	9.59%	0.78%	3.85%	4.02%	4.57%	4.34%	-4
LINGUISTICS & LITER	0.05%	0.43%	3.39%	4.46%	5.20%	3.92%	4
JUDICIARY SCEINCES	0.00%	0.43%	3.25%	1.61%	4.25%	3.85%	7
PSICOLOGY	0.00%	0.70%	1.06%	1.96%	4.49%	3.09%	7
PHILOSOPHY	27.49%	0.62%	2.27%	0.83%	2.46%	2.77%	-12
ECONOMICS & MANAG SC.	20.47%	0.31%	1.96%	1.68%	3.39%	2.16%	-11
MEDICINE	0.07%	6.35%	0.00%	0.00%	0.00%	0.00%	-5
PHISYCS & ASTRON.	0.07%	2.97%	10.97%	14.05%	0.00%	0.00%	-6
BIOLOGY	0.32%	11.70%	0.00%	0.00%	0.00%	0.00%	-7
CHEMISTRY	0.07%	9.79%	16.03%	11.46%	0.00%	0.00%	-7
ENGINEERING	0.36%	8.90%	0.00%	0.00%	0.00%	0.00%	-10

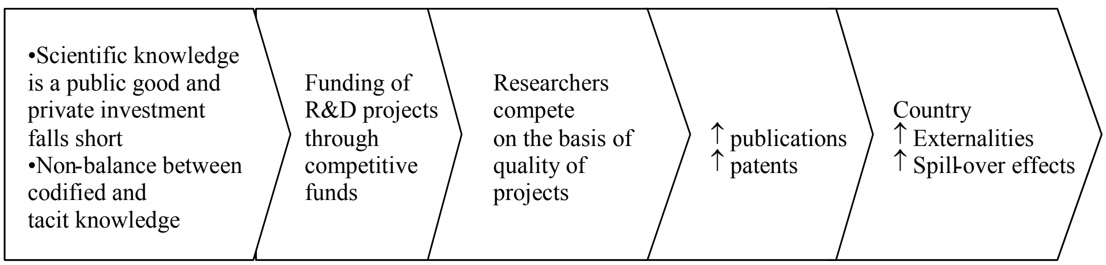
Source: Authors' elaboration.

II. THE THEORETICAL FRAMEWORK[4]

A. FONDECYT´s Rationale

The two fundamental features of FONDECYT's rationale are the public good nature of scientific research and the particular incentive system that governs the generation of high quality codified knowledge. Figure 2 synthetically represents the FONDECYT's rationale.

Figure 3 – FONDECYT's Rationale



Source: Authors' elaboration.

The public good nature of scientific knowledge provides the prime and basic justification for the public financing of research projects. Since the seminal works by Nelson (1959) and Arrow (1962), scholars have frequently defined scientific knowledge as a durable public good, i.e. non-excludable, non-rival and cumulative. In particular, the impossibility to completely appropriate the benefits or externalities arising from the generation of scientific knowledge causes a difference between the private and the social marginal return of science, making investment fall short of optimal levels. Furthermore, the non-rival and cumulative character of new knowledge intensifies the difficulty to create incentives that can compensate for the non-appropriable profits. Finally, the uncertainty and indivisibility of knowledge investments cause an even greater suboptimality in the allocation of resources.

However, according to Dasgupta and David (1994), the justification for the public support to scientific research goes beyond the need of correcting "market failures". Their argument rests on the assumption that the quality of being public (non tacit) is not inherent to knowledge. Indeed, researchers can make the decision to codify knowledge and make it available as information instead of

[4] This section follows OVE's survey on Economics of Science (OVE 2006) and Chudnovsky et al. (2006).

maintaining it in tacit form (secret form). In this framework, the public funding should also aim at providing the right incentives to maintain balanced allocation of the research effort between scientific and technological research.

Finally, the works of evolutionistic scholars provide alternative justifications for the public funding of science. This literature criticizes the public good argument by claiming that learning and transmission costs could significantly diminish both the non-rival and cumulative character of knowledge (Pavitt 2005). The rationale for the public support of scientific research has to be found in the dynamic and evolutive nature of the knowledge creation process. Public investment in science should foster systemic learning capabilities by training scientists (Salter and Martin 2001), developing new methods (Rosenberg, 1992), creating knowledge networks (Lundvall, 1992) and increasing the capacity to solve problems (Patel and Pavitt, 2000).

The rationale of the particular mechanism embedded in the public financing of scientific research can be referred to the debate on the most efficient way to provide public support to scientific activities. In this framework, scholars and policy makers seem to have identified three main strategies: first, the government uses public resources to directly produce and diffuse scientific research through state-owned organizations where the scientists are public employees (the French CNRS model). Second, the government grants property rights to private researchers to foster the production of scientific knowledge, mitigating the non-appropriability problem. Third, the government grants subsidies to scientist to finance their research activities. The FONDECYT clearly falls into the subsidy category.

The FONDECYT fund supports scientific research in Chile by providing grants through a competitive mechanism based on quality and experience. This specific competitive mechanism pursues a twofold objective: to increase the research quality and to improve the allocation of research investments. With reference to the former, the fund aims at stimulating the production and diffusion of high quality scientific outputs by making scientists apply for public resources. Previous literature suggests that the optimum incentive for scientists should be based on three components: a fixed monetary salary to stimulate the election of the scientific career, a variable compensation on the basis of performance, and non-monetary rewards based on scientists' social prestige (Carillo and Papagni, 2004).[5] With reference to the latter, the competitive mechanism aims at improving the allocation of resources among research topics by inducing

[5] The three components are strictly interdependent: through the achievement of better results the scientist obtains greater recognition on the part of her peers, she is able to see her wage increased, to receive prizes, scholarships and to even send signals to the market through the acquired prestige.

scientists to compete for the definition of national research priorities. As a result, this structure of incentives should lead to the generation and diffusion of high quality scientific output that could positively affect the set of technological opportunities of the NIS (Merton 1973).

These overall competition's benefits notwithstanding, some potential trade-offs are embedded in the specific parameters adopted in the selection process. Gambardella (2001) provides evidence of the effectiveness of funding scientists on the basis of their publication profile (excellence or experience criterion). This selection criterion not only leads to more and better publications, but it also reduces the probability of project failure. However, the adoption of the experience criterion may lead to the concentration of funding in a limited number of scientists or topics and, thus, reduce the variety of the research portfolio. Indeed, Molas-Gallart and Salter (2004) criticize the excellence criterion arguing that research variety increases the probability of obtaining valuable research results. In this direction, criteria based on the quality of the research proposals usually assume more risks of project failure as a counterpart for research diversification. Additional allocation criteria, such as the portfolio system proposed by Scherer and Harhoff (2000) aim at pursuing a greater variety of research topics - diversification – and access to funding for new groups and younger researchers, thus increasing the program's outreach.

The FONDECYT program, as other scientific research funds, adopts a mix of criteria that try to balance the abovementioned tradeoffs. The FONDECYT's evaluators rank the research proposals on the basis of four weighted criteria: i) the quality of the research proposal (35%); ii) the project viability (25%); iii) the ability and productivity of the principal researcher (29%) and, iv) the ability and productivity of the secondary researchers (11%). As can be seen from the weight distribution, FONDECYT's selection process gives some preference to the quality of the research proposal criterion. However, for well renowned researchers, especially those with previous but not necessarily current good publication performance, their CV may affect more than the project quality compared to a younger, unknown researcher.

B. Expected Outcomes and Determinants of Scientific Productivity

How should we evaluate the results of public support to science? The most generally accepted approach has been to use bibliometric data, since in general it is accepted that the number of publications can be a good measure of the production of codified knowledge and the possibility of access to this knowledge.[6]

Following Stephan (1996), a usual form to measure the importance of a scientist's contribution is through the number of her publications with some weighting to correct for the quality of her outputs. The typical way to control for quality is to use the impact factor of the journals where those outputs were published.[7] Nevertheless, Amin and Mabe (2000) notice that this measurement of quality depends on the field, the type and the size of the journal. In addition, they notice this indicator fluctuates from year to year and that it does not always provide an appropriate measure of the quality of a scientist's publications. For this reason, this measure should be always complemented with a direct measurement of citations to the articles produced by each scientist.

Crespi and Geuna (2004) point out the importance of incorporating lags in the estimations of the results of scientific research, in order to catch the delay between the reception of the funds and actual publication. In an econometric study of a panel of OECD countries, they show that to identify the maximum impact of a given increase in the science budget on publications and citations it is necessary to wait between 5 to 6 years.[8] Moreover, Crespi and Geuna (2005) emphasize that different fields are characterized by different propensities to publish in recognized journals, as well as by different time lags in reaching publication.

The literature on the economics of science provides an increasing amount of empirical evidence regarding those variables that affect the number of publications by scientists. Although comparability across many of these contributions is limited due to differences in methodologies, sample sizes, scientific fields and time frames, they turn out to be a useful guide for our empirical strategy.

[6] Diamond (1986) provides empirical evidence for the relevance of this mechanism to determine salaries increases and promotions at universities. Debackere and Glänzel (2003) analyze the results of an experiment that consisted in distributing funds to Flemish universities on the basis of bibliometric output.

[7] Impact factors are no more than a measurement of the frequency with which the "average" article of a journal was mentioned in a certain year. In particular, the impact factor is calculated dividing the number of citations received by articles published during the two previous years in a given journal by the number of publications in those years in the same journal.

[8] In this direction, Arora and Gambardella (1998) consider the impact of public funding to economic researchers in the United States using the publications weighted by citations in a window of 5 years after the decision to grant the funding was taken.

Several studies modeled scholarly productivity as a function of observed personal characteristics, research environment and, only very few of them, researchers' abilities. The effect of age on scientific production has been widely discussed.[9] Stephan (1996) reviews the findings of works that adapted the frame of the human capital theory to develop life-cycle models. These studies conclude that the publication rate of a scientist grows initially, but it soon begins to decline around half of its career. The empirical evidence, based on panel data estimations, usually shows that the turndown in the quadratic relation takes place between 45 and 52 years and that the same one can differ by area of knowledge.[10]

The difference in productivity by gender has been widely debated as well. Some findings suggest women's publication rates are lower than men's ones after controlling for individual characteristics such as age, education, experience and scientific field.[11] However, Long (2001) suggests that this difference was manly due to omission of the academic rank and that once the probability of acceding to a certain position in academy is taken into account, gender differences would not have effect on scientific productivity. Also, findings by Koplin and Singell (1996) suggest that although the total amount of publications might be lower for women, these differences disappear when controlling for publications quality. Indeed, their findings for a sample of researchers in the field of economics imply that women tend to publish less than men at comparable institutions. However, after adjusting for the quality of the publications set, women tend to be more productive than men at comparable institutions.[12]

Additional variables also affecting research productivity are the level of education (normally measured by the possession of a PhD degree and the prestige of the institution in which it was obtained)[13], the availability of other sources of incomes (Stephan 1996), the number of previous publications, the score obtained during research project applications (Arora and Gambardella, 1998) and the size and quality of the research laboratory (Turner and Mairesse 2005).

[9] Arrow and Capron (1959)

[10] See for example: Bernier et al. (1975), Cole (1979), Levin and Stephan (1991), Turner and Mairesse (2005).

[11] See for example: Cole and Zuckerman (1984), Hamovitch and Morgenstern (1977), Broder (1993), Xie and Shauman (1998).

[12] For more details see NSF Special Report Gender Differences in the Careers of Academic Scientists and Engineers: A literature review.

[13] See Buchmueller et al. (1999), Turner and Mairesse (2003).

III. THE EVALUATION STRATEGY

After reviewing the rationale of the FONDECYT program in light of the economic of science literature and having identified its potential outcomes, in this section we address the main research questions of this study: i) what is the FONDECYT's impact on the number of publications produced by the financed scientists? (ii) What is the FONDECYT's impact on the quality of the publications produced by the financed scientists?

To answer these questions, we have to deal with the problem that the FONDECYT completely lacks a monitoring system for collecting data and tracking outcomes of interest for both beneficiary and non-beneficiary researchers. We overcome this problem by using administrative records combined with secondary data on the publication profile of the scientists who applied to the program between 1988 and 2004 (Figure 4). We then use this information to perform a quasi-experimental impact evaluation through a regression discontinuity design.

A. Data Description

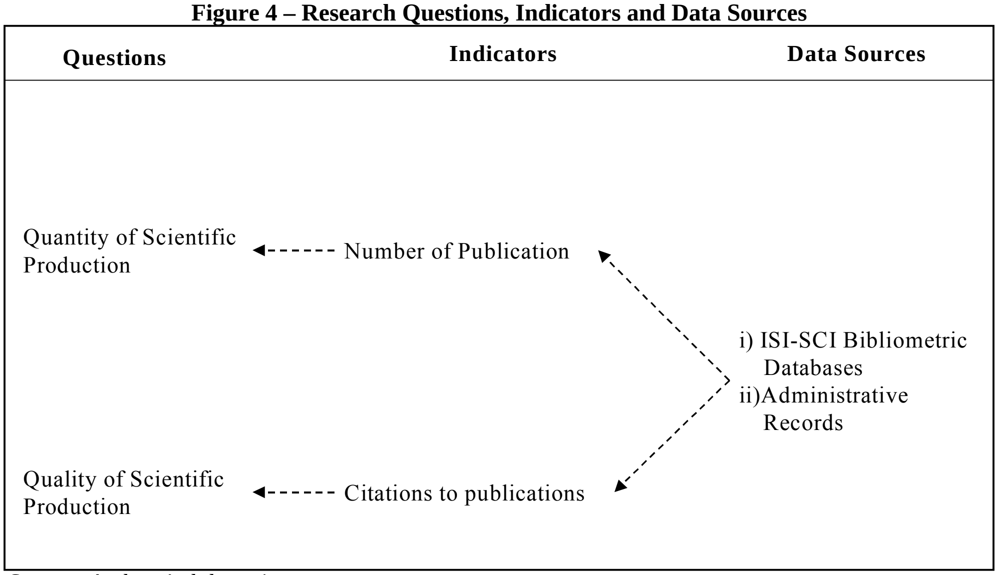
To carry out this evaluation, we set up a specific database in cooperation with CONICYT's Information Unit. The data gathering process was organized into three phases: (i) identification of the population of reference; (ii) attribution of the projects to the treatment and control groups; (iii) attribution of publications and citations to the selected research projects.

a. *Identification of the population*: the population of reference included (i) all projects that received financial support from the program between 1988 and 2004 and, (ii) a stratified sample of projects submitted to the program, which were not financed because ranked below the threshold defined for being admitted to the financing. The sample was stratified on the basis of the raking obtained in the "call for proposal".

b. *Definition of the treated and control groups*: projects were attributed to the treatment or control groups on the basis of the results of the first competition to which they were submitted. Given that the program allows for the re-submission of projects, projects that were rejected in the first submission but that were accepted in later competitions were not considered in the analysis. The inclusion of "switching projects" could contaminate the treatment and control samples.

c. *Attribution of the bibliometric data*: for both the treated and control groups were counted only those publications included into the ISI-SCI database that could be clearly attributed to the previously identified (accepted and rejected) projects. For this a special routine was designed that allows for counting only those future publications clearly related with the research project.[14] It is worth noting that the search includes all publications printed up to December 2005, therefore no explicit lag was considered. In this framework younger or more complex projects may experience some censoring. As we discuss later, we include in the sample only research projects that started before year 1995 to minimize this potential problem.

Figure 4 – Research Questions, Indicators and Data Sources



Source: Authors' elaboration.

Table 2 shows the main descriptive statistics of our working sample. There are 1,531 research projects in our sample, 522 research projects in the treatment group and 1,009 research projects in the control group. When analyzing the main descriptive statistics of the two groups of projects we get that, 'on average', treated projects produced 6% more publications than projects in the control group (using log publications to correct for the severe skewness in this variable), while

[14] This particular database structure allows us to concentrate on the FONDECYT's effectiveness in selecting projects that perform better than those supported by alternative sources of financing. Although this structure limits the possibility of identifying any FONDECYT's impact on other scientific works carried out by the same researchers (i.e. spillover effects), this structure is the most consistent with the relevance attributed by FONDECYT to project selection, rather than to researcher selection.

these publications received 6% more citations (a quality adjusted indicator of output). Projects in the treatment group had a much lower rank than projects in the control group (that is, they were closer to the top in terms of evaluation scores), however both groups of projects had similar duration (2.3 years) and similar size in terms of the number of researchers in the research team.[15]

Table 2 – Descriptive Statistics

VARIABLE		GRANT=0			GRANT=1			TOTAL		
		Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs
Publications	(Count)	3.37	5.17	1009	3.30	3.43	522	3.34	4.65	1531
Citations	(Count)	15.42	25.48	1009	20.53	29.38	522	17.16	26.97	1531
Publications	(Log)	0.77	0.84	1009	0.83	0.80	522	0.79	0.83	1531
Citations	(Log)	1.94	1.33	1009	2.20	1.42	522	2.03	1.37	1531
Ranking	(Standardized)	0.55	0.72	1009	-1.06	0.43	522	0.00	0.99	1531
Duration	(Years)	2.30	0.73	1009	2.37	0.69	522	2.32	0.71	1531
Researchers	(Count)	4.50	2.41	1009	4.71	2.51	522	4.57	2.44	1531

Source: Authors' elaboration.

B. Econometric Strategy

The impact of public financing of research funds such as the FONDECYT is a much less explored field than other policy evaluations. The identification of the impact of public financing has to deal with a quite clear potential selection bias: research projects that are the best candidates for funding are also those projects that would have the largest expected output in the absence of funding. In order to understand the evaluation problem, it is useful to specify the following knowledge production function:

$$Y_{i,t+j} = \tau D_{i,t} + Z_{i,t}\mathrm{B} + \alpha_i + \varepsilon_{i,t+j} \qquad (1)$$

where $Y_{i,t+j}$ is the research output (the number of publications in refereed journals by a supported project *i* during *j* years after the project), D_{it} is a dummy variable that takes the value of one if project *i* receives the grant at time *t*, τ is the impact for project candidate *i* from receiving a grant, Z_{it} is a vector of observable determinants of research outputs and α_i represents unobserved (to the evaluator) project quality. A primary obstacle to identification is the non-random

[15] It is worth reminding that the dataset includes only the publications generated by the projects submitted to FONDECYT, and not the total publications by the researchers.

assignment of treatments. In particular, selection for support on the basis of unobserved quality (by both applicants and CONICYT) may lead to a non-zero correlation between the error term and the treatment, $cov(D_{i,t}, \alpha_i) \neq 0$. In this case, the treatment effect estimated using OLS might not reflect the program's causal effect on project performance.

In order to overcome the selection problem, we adopted the so-called regression discontinuity design. This technique utilizes a discontinuity in the probability of selection that occurs at a particular threshold with respect to some index of quality to identify the treatment effect separately from the impact of quality[16]. According to this design, assignment is solely based on whether a pre-intervention measure is above/below an established threshold. For instance, consider the case in which candidates are split into two groups according to whether the pre-intervention measure (for example, average evaluation by peers in the FONDECYT's case) is above or below a specified threshold. Those who scored above the threshold receive the grant while those who score below are denied it.

The regression discontinuity design approach relies on the maintained hypothesis that individuals with a score just below the threshold score are similar in their observed and unobserved characteristics to individuals with score just above the threshold score.

This design features both advantages and disadvantages. On the one hand, by exploiting the fact that subjects assigned to the control and treatment groups differ solely with respect to the variable on which the assignment to the intervention is established (and with respect to any other variable correlated to it), one can control for the confounding factors just by contrasting marginal participants to marginal non-participants.

In this context, the term marginal refers to those research projects not too far from the threshold or cut-off point for selection. By contrasting marginally treated and marginally control research projects, the method allows for identifying the mean impact of intervention locally with respect to the cut-off. Intuitively, for the identification to hold it must not be the case that a spurious discontinuity in the relationship between the outcome and the variable on which selection is based happens to coincide with the cut-off point.

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[16] The regression discontinuity design estimator was introduced by Thistlethwaite and Campbell (1960). In the economic literature this estimator has been recently used by Van Der Klaauw (2002), DiNardo and Lee (2002), Black (1999), and Angrist and Lavy (1999). The identification and estimation of treatment effects are discussed in Hahn, Todd, and Van der Klaauw (2001) and Imbens and Lemieux (2007)

On the other hand, the design features two main limitations. First, its feasibility is by definition confined to those instances in which selection takes place based on an observable pre-intervention measure or on the basis of a deterministic process. Second, even when the design is feasible, it only identifies the mean impact at the threshold for selection.

Based on (1), the implementation of the regression discontinuity approach is based on estimating the following regression:

$$Y_{i,t+j} = \tau D_{i,t} + (x_{i,t} - c_t) + \gamma (x_{i,t} - c_t) D_{i,t} + u_{i,t+j} \quad \forall = i,t \left(c_t - h \le x_{i,t} \le c_t + h\right) \qquad (2)$$

Where the new variable $x_{i,t}$ is the ranking given to the research project during the assessment and c is the cut-off ranking (that changes for different years). The treatment estimator is given by τ while the interaction term controls for the possibility that the slopes of the outcome function at both sides of the cut-off be different. Finally h is the 'bandwidth' that determines how far each observation should be from the cut-off point in order to be included in the estimation sample. This version of the regression discontinuity approach is called in the evaluation literature as '*Sharp Regression Discontinuity'* (SRD) design.

In order to provide unbiased results of treatment impacts a SRD design requires that the forcing variable or ranking captures all the information regarding the quality of the research projects and that funding decision be based only on this rank. The situation becomes more complicated when the granting agency, based on additional information not captured on the rank assessment, makes a decision 'to pass' some projects that otherwise would have been rejected (projects just above the cut-off rank) and to reject some marginal projects that otherwise would have been passed (project just below the cut-off rank). In this case some sort of sample selection bias 'at the margin' could still remain. This context is known as a '*Fuzzy Regression Discontinuity*' (FRD) design. In this case we need to estimate (2) by using instrumental variables. Following Jaffe (2002) a good instrument under this situation is a dummy variable that takes a value of 1 whenever the ranking is below the cut-off. In other words the instrument would be:

$$1\{x_{i,t} \le c_t\} \qquad (3)$$

This instrument should be highly correlated with the treatment dummy ($D_{i,t}$) by construction, but because we are already controlling for the ranking in the regression ($x_{i,t}$), it should not be correlated with the error term. Both *SRD* and *FRD* approaches will be applied in this paper.

IV. EMPIRICAL RESULTS

A preliminary stage of our analysis studies the relationship between the raking obtained by projects and the number of ISI publications (citations) generated by the projects. For this purpose, we estimate this relationship through a local linear regression, where the dependent variable is the log of the frequency of publications (citations) and the independent variable is the ranking obtained by the projects. In order for the regression discontinuity approach to be valid, we should observe some sort of discontinuity of the output function at or near the cut-off point.

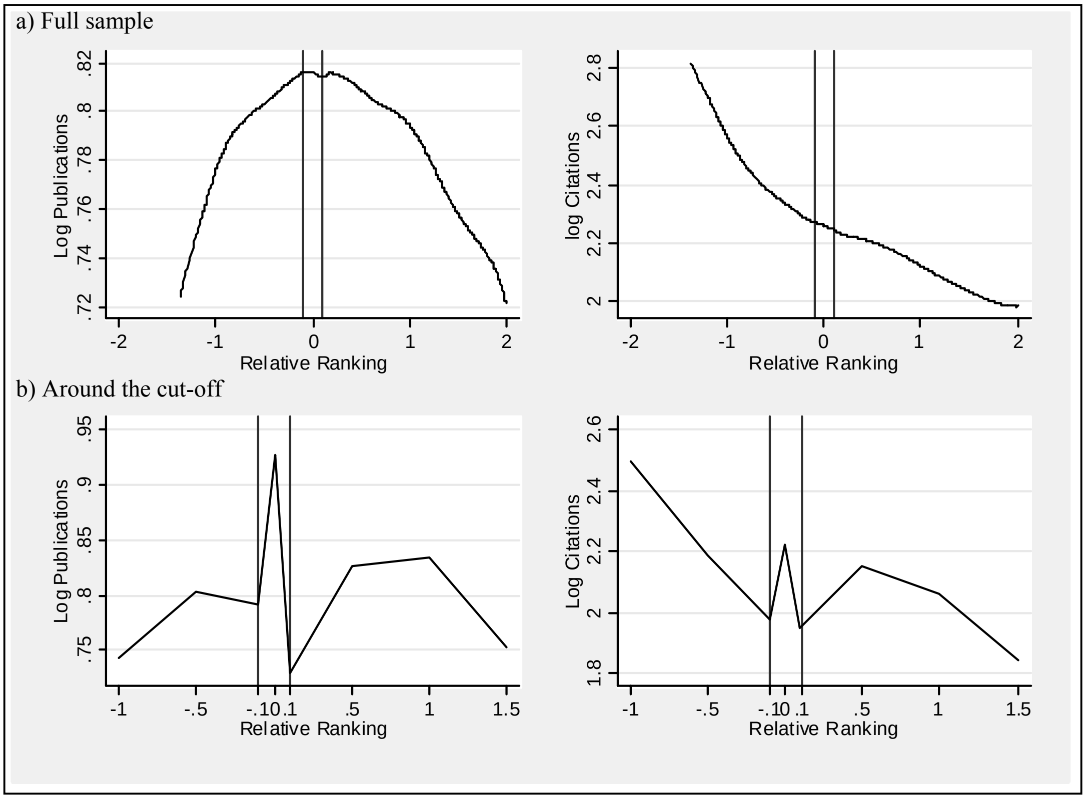
Results can be seen in the two top panels of Figure 5. In order to facilitate the interpretation we have normalized the ranking of each year relative to the cut-off point. In other words in each year the cut-off corresponds to the zero ranking. The top left panel of Figure 5 shows the local linear regression results for publications. Quite surprisingly we found an inverted U relationship between ranking and publications. This means that supported projects at the top of the ranking are not the ones that produced more publications. We also observe a small discontinuity in the number of publications around the cut-off, which could suggest some sort of impact by FONDECYT on those marginal projects. The top right panel in Figure 5 shows the local linear regression results for citations. In this case we observed a smooth declining function between citation and the ranking, suggesting that project with the highest score produced higher quality publications (publications that were cited more often). Additionally, we do not see evidence of any discontinuity in the outcome function around the threshold. An interesting conclusion of combining these two plots is that FONDECYT's reviewers could have tended to give more weight to projects that, although had less expected publications, were expected to produced high impact publications (in terms of citations).

One problem with the two plots in the top panels of Figure 5 is that the local linear regression is estimated across the full support of the forcing variable. According to Imbens and Lemieux (2007) this could harm visual clarity of any discontinuity in the outcome functions. In order to improve the analysis, we compute the average outcome for several intervals to both sides of the cut-off (but excluding the cut-off itself). The bandwidth is computed to increase the importance of those observations near the cut-off. The bottom panels of Figure 5 show the results of this approach[17]. The bottom left panel suggests that there is an

[17] The following intervals were considered: (0.01-0.05), (0.05-0.10), (0.10-0.50), (0.50-1.00) and (1.00-1.50).

important discontinuity for publications. However, the bottom right panel indicates that impact is expected to be much smaller for citations.

Figure 5 –The Relationship between Ranking and Research Outputs of FONDECYT Projects

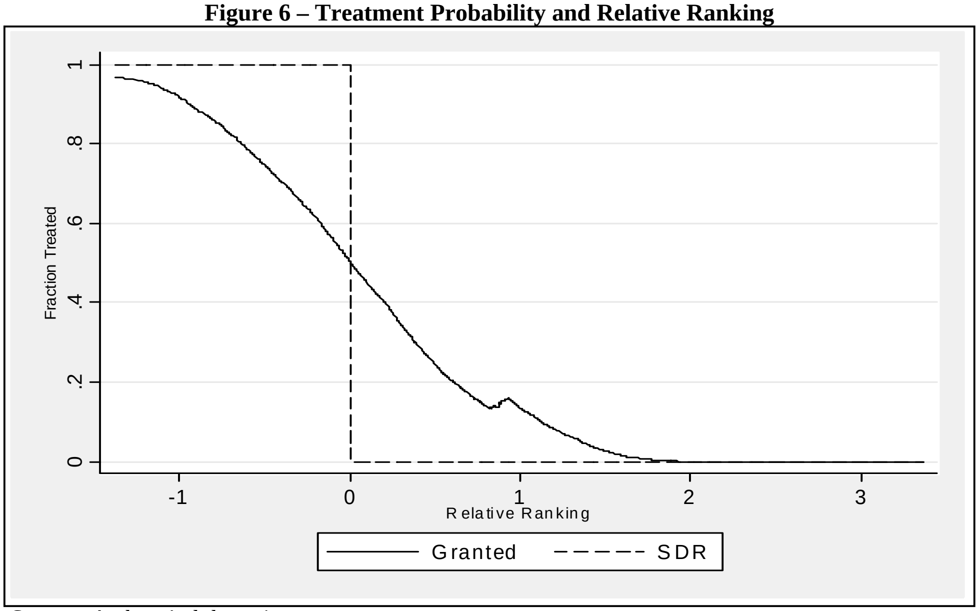


Source: Authors' elaboration.

Before proceeding with the estimation it is important to determine what sort of regression discontinuity design should be used for the analysis. One way of doing this is by plotting treatment probabilities by projects' rankings and seeing if there is a sudden drop in this probability at the cut-off.

Figure 6 shows the results of this analysis. The figure plots the predicted treatment probability, estimated using local linear regression, and the expected treatment probability under SRD. The degree of overlap between these two functions is not very high. This suggests that not all projects with ranks below the cut-off point were selected for financing and that not all the projects with ranks above the cut-off point were rejected. In other words, the results indicate that there is significant mobility "at the margin" and that a FRD approach might be more adequate for this analysis.

Figure 6 – Treatment Probability and Relative Ranking



Source: Authors' elaboration.

In what follows we present the impact results for publications and citations (both in logs) using OLS and IV techniques. Table 3 summarizes the results when the dependent variable is (log) publications and the estimation technique is OLS. Several bandwidths were considered. Overall we found that in the sample around the cut-off (bandwidth of 0.05) there is a positive impact of FONDECYT of around 35%, which is not statistically significant. However if we increase the bandwidth slightly to 0.10, we obtain a positive and significant impact of 42%, suggesting that the insignificant results for the narrowest bandwidth might be due to the small sample size. Consistently with the outcome function plotted in Figure 5, the estimated impact declines when we increase the bandwidth and the sample size.

The outcome functions plotted in the left panels of Figure 5 suggest that the relationship between publication and the ranking is quadratic. In order to test for this and to see how robust these results are to a non-linear function for the outcome, we estimate equation (2) by including a quadratic term (and its interaction). Table 4 summarizes the results of this approach. In this case we have that estimated impacts are higher and significantly different from zero across different sorts of bandwidths.

Table 3 – Treatment Effects for Publications, OLS Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
COEFFICIENT	**All**	**H=0.05**	**H=0.10**	**H=0.50**	**H=1.00**	**H=1.50**
D	0.132*	0.355	0.423**	0.369***	0.252***	0.177**
	(0.075)	(0.23)	(0.17)	(0.094)	(0.086)	(0.081)
X	0.0242	-1.222	-0.950	0.918***	0.319***	0.0894
	(0.036)	(6.63)	(2.07)	(0.24)	(0.12)	(0.067)
XxD	0.0459	-14.34	-3.366	-0.922***	-0.247	0.00205
	(0.085)	(10.1)	(3.26)	(0.32)	(0.15)	(0.10)
Constant	0.796***	0.808***	0.830***	0.746***	0.789***	0.813***
	(0.058)	(0.22)	(0.16)	(0.081)	(0.074)	(0.068)
Observations	1531	65	111	452	870	1179
R-squared	0.01	0.41	0.31	0.12	0.04	0.02

Robust standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1, year dummies included

Source: Authors' elaboration.

Table 4 – Treatment Effects for Publications, OLS Estimates, Quadratic Ranking

	(1)	(2)	(3)	(4)	(5)	(6)
COEFFICIENT	**All**	**H=0.05**	**H=0.10**	**H=0.50**	**H=1.00**	**H=1.50**
D	0.168**	0.647**	0.608***	0.370***	0.312***	0.282***
	(0.081)	(0.30)	(0.22)	(0.11)	(0.085)	(0.082)
X	0.118	-0.881	-2.305	1.441***	1.166***	0.718***
	(0.10)	(5.94)	(2.44)	(0.29)	(0.26)	(0.19)
X^2	-0.0400	237.9	58.65	-1.971**	-1.044***	-0.468***
	(0.043)	(247)	(41.2)	(0.96)	(0.33)	(0.14)
XxD	-0.283	-15.22	-1.985	-1.702***	-1.276***	-0.824***
	(0.18)	(9.34)	(3.61)	(0.38)	(0.30)	(0.24)
X^2xD	-0.222	-466.5	-59.98	0.676	0.755*	0.244
	(0.15)	(360)	(57.0)	(1.29)	(0.40)	(0.20)
Constant	0.758***	0.575**	0.660***	0.806***	0.744***	0.708***
	(0.067)	(0.27)	(0.19)	(0.091)	(0.069)	(0.067)
Observations	1531	65	111	452	870	1179
R-squared	0.02	0.44	0.32	0.13	0.06	0.03

Robust standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1, year dummies included

Source: Authors' elaboration.

Table 5 shows the results when assuming a FDR design and estimating using instrumental variables. We use the dummy variable defined by (3) as instrument for the treatment dummy and its interaction with the ranking as instrument for the interaction between the treatment dummy and the ranking. The results in Table 5 show that the treatment's impact is not significant and numerically much smaller than it was when using OLS estimates. Overall these results suggest that the program did not have any significant impact when one controls for selection at the margin.

Table 5 – Treatment Effects for Publications, TSLS Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
COEFFICIENT	**All**	**H=0.05**	**H=0.10**	**H=0.50**	**H=1.00**	**H=1.50**
D	-0.0840	0.531	0.262	-0.426	-0.118	-0.119
	(0.13)	(0.52)	(0.40)	(0.51)	(0.23)	(0.16)
X	-0.0477	13.98	5.422	-0.256	-0.0475	-0.0913
	(0.045)	(15.2)	(7.98)	(0.62)	(0.19)	(0.092)
XxD	0.0172	-49.69*	-17.80	-0.259	-0.0243	0.0681
	(0.099)	(25.3)	(17.3)	(0.46)	(0.17)	(0.11)
Constant	0.896***	0.872***	0.919***	1.108***	1.002***	0.974***
	(0.071)	(0.31)	(0.25)	(0.22)	(0.12)	(0.093)
Observations	1531	65	111	452	870	1179
R-squared	0.01	0.16	0.15	.	0.02	0.01

Robust standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1, year dummies included

Source: Authors' elaboration.

Tables 6 and 7 summarize the results for the citations. As the outcome plots of Figure 5 suggest, the impact results for citations are much smaller than the ones for publications. When using OLS (Table 6), the treatment variable is not significant, except when the bandwidth is 0.50. On the other hand, when using TSLS (Table 7), the results for the two narrowest bandwidths are positive but not statistically significant while for larger bandwidths they are negative and statistically significant.

Table 6 – Treatment Effects for Citations, OLS Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
COEFFICIENT	**All**	**H=0.05**	**H=0.10**	**H=0.50**	**H=1.00**	**H=1.50**
D	0.0741	0.492	0.0714	0.291**	0.137	0.0686
	(0.12)	(0.34)	(0.27)	(0.15)	(0.13)	(0.13)
X	-0.0614	-1.282	-4.539	0.824**	0.187	-0.0749
	(0.052)	(9.48)	(3.24)	(0.37)	(0.17)	(0.098)
XxD	-0.0230	-19.60	1.022	-0.668	-0.190	0.00967
	(0.14)	(12.5)	(5.03)	(0.52)	(0.24)	(0.16)
Constant	2.224***	2.546***	2.744***	2.265***	2.222***	2.308***
	(0.087)	(0.38)	(0.28)	(0.13)	(0.11)	(0.10)
Observations	1531	65	111	452	870	1179
R-squared	0.17	0.45	0.35	0.20	0.16	0.16

Robust standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1, year dummies included

Source: Authors' elaboration.

Table 7 – Treatment Effects for Citations, TSLS Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
COEFFICIENT	**All**	**H=0.05**	**H=0.10**	**H=0.50**	**H=1.00**	**H=1.50**
D	-0.206	0.450	0.267	-1.422*	-0.647*	-0.434*
	(0.19)	(0.81)	(0.65)	(0.86)	(0.37)	(0.25)
X	-0.148**	16.82	-1.518	-1.377	-0.456	-0.344**
	(0.065)	(21.3)	(10.4)	(1.00)	(0.29)	(0.14)
XxD	-0.0887	-60.45	-5.215	0.142	0.0167	0.0304
	(0.16)	(36.6)	(23.9)	(0.76)	(0.27)	(0.18)
Constant	2.344***	2.741***	2.662***	2.989***	2.612***	2.552***
	(0.10)	(0.57)	(0.41)	(0.37)	(0.19)	(0.14)
Observations	1531	65	111	452	870	1179
R-squared	0.16	0.32	0.33	.	0.13	0.15

Robust standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1, year dummies included

Source: Authors' elaboration.

The above results suggest that the program has not been successful to increase both the quantity and the quality of research outputs emerging from Chile's science and technology system. As suggested in section II, the subsidies given by a national research fund to an individual researcher or research team can be seen as affecting the relative rewards from research compared with other activities such as teaching and consultancy. From the individual's point of view therefore, receiving a subsidy may induce the researcher to free time from consultancy and allocating that time to research or to put more effort on the use of a given research time. By this way, a research subsidy may stimulate research efforts and outputs. If these hypotheses were true, we could have expected a positive impact from FONDECYT. Hence, why did it go wrong?

Funding for scientific research might come from many sources (contracts with other government entities, consultancy with private companies, support from multilateral organizations, aid from international donors, etc) and these different sources of funds can be either complement or substitute. That is, it is not possible to guarantee that a given increase in government funds to science, through one particular program, is going to be linearly transmitted to the research budget: the presence of a 'crowding in' (or 'crowding out') phenomenon in relation to other available research sources must be taken into account. There are situations when a positive correlation between national research funds and other resources might be expected; for instance, resources from national research funds can be used to finance fixed capital costs (such as the building of laboratories), allowing the researches to price at variable cost research services to other government departments or even the business sector. Resources from national research funds can also be used to finance the riskier component of the research project (i.e. the basic research) and then other sources (including perhaps private funding) can be used to complete the development phase of the research project. 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

However, the relationship might also lead to a substitution effect. This would occur in situations where the type of project being funded by national research funds was very similar to the types of projects funded by other sources of funds. The issue here is that it is not possible to fully understand the effects of a given increase in public funding through a program such as FONDECYT on the different research outputs without taking account of these various relationships. Although the empirical analysis of these conjectures is outside of the scope of the current paper, they could help to understand why the program did not have any result.

Finally, possibilities for 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 (projects that are likely to have a range of alternative sources of funds). These are projects that could have been financed by other sources of funds, suggesting that the public funds can in fact be superfluous (for more details see the accountancy framework in Lach, 2001).

V. CONCLUSIONS

The impact evaluation of the FONDECYT does not show clear evidence of any significant impact neither in terms of publications nor in terms of quality of publications. Although simple OLS estimations show some positive impacts of the program, these results do not hold when we correct the selection bias through an instrumental variable technique. In other words, evidence suggests that although the Chilean research activity has grown both in terms of quantity and quality, these achievements cannot be clearly attributed to the FONDECYT program. In fact, not only were the projects rejected by FONDECYT often funded by alternative sources of financing, but these rejected projects also performed at the margin as well as the ones funded by FONDECYT.

Although these results should be interpreted with some caution, since the specific technique adopted estimates only local effects[18], this lack of impact is certainly concerning and calls for a critical review of the program. In particular, the results of this evaluation suggest that this review should focus on the program targeting.

First, the program may have targeted the wrong researchers. A sort of "Matthew effect"[19] may have led the FONDECYT's administrators to target already established researchers with access to many funding opportunities, inducing a simple substitution among alternative sources of financing. The first stage of our analysis shows an unexpected feature of the FONDECYT's selection process. Although the projects ranked better tend to perform better in terms of citations, they not necessarily perform better in terms of number of publications. This inverted U-form of the relationship between ranking and number of publications could be a sign of the overvaluation of projects submitted by consolidated researchers on the basis of their past performance, vis-à-vis those submitted by younger and less experienced researchers.[20] Although we may reject that FONDECYT acts as a simple prize for renowned scientists who publish less but with higher quality, these results may indicate that a non-competitive process is in place discouraging the applications by new entrants.

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[18] The so-called Local Average Treatment Effect (LATE), that is the potential effects of the program on a restricted group of beneficiaries compared with a restricted group of non-beneficiaries at the threshold level.

[19] With the term "Matthew effect" Robert K. Merton (1968) describes how prestige could bias the allocation of resources and the attribution of rewards toward eminent scientists. The definition comes from Matthew 24:9: "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath".

[20] In an effort to improve targeting towards less experienced researchers, CONICYT has recently introduced a FONDECYT's line of financing specifically devoted to young researchers.

Second, the program may have targeted the wrong type of research projects. Excessive risk aversion may have led to target applied research projects with lower fixed costs, lower risk and, in some case, lower originality than expected. This potential bias could have induced the researcher to submit projects that minimize the risk of failure,[21] projects for which various source of financing are potentially available.

This paper has to be considered just a first attempt to evaluate the FONDECYT program. Further evaluations should test the impacts on the full set of publication of the project leader (not only those publications that could be unambiguously attached to the funded project). This further analysis would allow estimating the potential spillover effects between those projects funded by FONDECYT and other research projects conducted by the same scientist. The only way of internalizing these spillovers would be to measure the program's impact on the full portfolio of publications of the treated and control scientists.

Finally, the FONDECYT's impact evaluation would benefit from the assessment of the heterogeneity of impacts in terms of (i) characteristics of the researchers, (ii) characteristics of the research projects and, (iii) scientific fields. With reference to (i) and (ii) we have already pointed out how a biased targeting both in terms of researchers and research projects could have limited the FONDECYT's effectiveness. With reference to the latter, evidence suggests there are fields where the return in terms of publications and citations for each dollar allocated is sometimes larger in Chile than in comparable countries (Contreras et al, 2006). Again, only an expanded database would allow these research extensions.

[21] An incentive to submit less risky projects could have been generated by the fact that the subsidy could be partially conditional to the actual publication in an ISI journal.

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