Public support to firm level innovation: an evaluation of the FONTEC Program*

Jose Miguel Benavente
Business School, Universidad de Adolfo Ibáñez, Santiago, Chile

Gustavo Crespi
Competitiveness and Innovation Division, Inter-American Development Bank (IDB), Washington DC, USA

Alessandro Maffioli
Strategy Development Division, Inter-American Development Bank (IDB), Washington DC, USA

Recebido: 22/03/2011 Versão revisada (entregue): 24/01/2012 Aprovado: 19/04/2012

Abstract

Latin American Governments have frequently adopted Technology Development Funds (TDF) to provide financial support for innovation activities of firms. In this paper, we analyzed the effectiveness of a Chilean TDF, the FONTEC program. We found that FONTEC's subsidies increased firm innovation investments in intangible assets (in particular R&D) and they also improved the linkages among actors in the innovation system. However, although we did not find any evidence of crowding-out effects, neither did we find any evidence of the leveraging

* This study was developed as part of "*IDB's Science and Technology Programs: An Evaluation of Technology Development Funds and Competitive Research Grants*", a project coordinated by the Office of Evaluation and Oversight (OVE) of the Inter-American Development Bank (IDB). We also thank to two anonymous referees for their helpful suggestions and comments. Benavente wants to thank Nucleo Milenio Initiative NS100017 "Intelis Centre" for their partial funding. The findings and interpretation of the authors do not necessarily represent the views of Inter-American Development Bank. The usual disclaimer applies.

of private financing for innovation (crowding-in). In terms of output additionality, FONTEC did significantly increase the employment and productivity of beneficiary firms. The findings with regards to skills are more mixed, but this could be affected by the poor quality of the skills variable in the survey.

KEYWORDS | FONTEC; Chile; Research and Development; Matching Grants; Policy Evaluation.

JEL Codes | O32, O38, H43.

Apoio público à inovação empresarial: uma avaliação do Programa FONTEC

RESUMO

Os governos latino-americanos recorrem frequentemente aos Fundos de Desenvolvimento Tecnológico (FDT) para apoiar financeiramente as atividades inovadoras das empresas. Neste estudo analisamos a eficácia do um FDT chileno, o programa FONTEC. Constatamos que os subsídios do FONTEC provocaram um aumento dos investimentos inovadores das empresas em ativos intangíveis (principalmente P&D), além de melhorarem as articulações entre atores no sistema de inovação. Entretanto, embora não tenhamos detectado indícios de *crowding out* (inibição), tampouco encontramos quaisquer evidências de aumento do financiamento privado da inovação devido aos subsídios (*crowding in*). Em termos de adicionalidade de resultados (*output additionality*), o FONTEC de fato aumentou a geração de emprego e a produtividade das empresas beneficiárias. As conclusões quanto a habilidades foram mais mistas, mas isso pode ter sido afetado pela baixa qualidade da variável habilidades na enquete.

PALAVRAS-CHAVE | FONTEC; Chile; Pesquisa e Desenvolvimento; Recursos de Contrapartida (*Matching Grants*); Avaliação de Políticas.

CÓDIGOS JEL | O32, O38, H43.

1. Introdução

Since the beginning of the 1990s, several Latin American countries have witnessed a systematic growth of public programs aimed at enhancing firm-level innovation. 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, different 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 schemes started in Chile in 1991 and they have been gradually replicated in Argentina, Brazil, Costa Rica, Colombia, Mexico, Panama, Peru, Paraguay and Uruguay.

Although almost twenty years have passed since the first subsidies of this kind were introduced, very little convincing empirical evidence exists regarding their impacts and effectiveness with regards to long-term firm performance. 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 as FONTEC. For this purpose, the paper considers two levels of potential impact: input additionality and performance (or output additionality).

We found evidence that subsidies granted by FONTEC increased firm-level investments in research and development. However, we ddid not find evidence of partial crowding-out effects between the subsidies and private financing by the beneficiary firms, which means that the average firm-level investment in innovation by a beneficiary firm increased by the full amount of the average subsidy. We also found a positive impact of the program on the firms' capabilities for interacting with external sources of knowledge. Finally, we found positive impacts of the program on employment, labor productivity and total factor productivity. The impact on productivity systematically grew over time. The effects on skills were mixed. On average we did not find evidence of impact on the skills content of firms' workforces, although we found some evidence of skills accumulation during the years after the treatment.

To evaluate FONTEC's impact, we used two different data sources processed with the collaboration of Chile's National Institute of Statistics: the National

Technology Innovation Survey (ENIAT) and the Annual Manufacturing Survey (ENIA). For both surveys we identified data on FONTEC beneficiaries and built control groups of comparative firms. This approach allows for working with official data, but has the associated cost of producing results that are valid only for the manufacturing sector. We adopted difference-in-difference and propensity score matching methods to estimate the program's impacts.

Following this introduction, the paper is organized as follows: Section I discusses FONTEC's antecedents and theoretical rationale. Section II presents the dataset used for the evaluation and discusses the econometric strategy. Section III summarizes the empirical results and Section IV concludes.[1]

2. The FONTEC Program: antecedents and rationale

2.1. The antecedents of Chile's science, technology and innovation policy

The recent evolution of the Chilean NSI has been remarkable. Indeed, during the last 20 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, since the early 1990s the Chilean authorities have set up a rather complex system of interventions, often supported by multilateral organizations such as the Inter-American Development Bank (IDB).[2]

In Chile, as in many other countries of Latin America, the institutional setting for Research and Development (R&D) has been historically based on a network of universities and technological institutes supported and controlled by the public sector. Indeed, since the mid-19th century, universities provided the main network for basic research and the nuclei for most of the applied research conducted in the country (BENAVENTE; CRESPI, 1998). Later on, during the 20th century, a network of technological institutes was created by the State with the aim of supporting the industrialization process and increasing the productivity of natural resources

1 We would like to thank the reviewer for her/his comments. All of them were very relevant and enabled us to improve the clarity of the paper.

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.

(in particular in the agriculture, forestry and mining sectors). In addition to this, most of the technological development activities developed in the productive sectors were carried out by a set of publicly owned enterprises established after WWII. The National Development Agency (CORFO), established in 1939, played a pivotal role in the coordination and financing of the overall industrialization process, including technological development.

The process of trade liberalization and privatization in the mid-1970s led to increasing participation by the private sector in economic activity in many sectors previously considered strategic (with the exception of copper mining) and to a reduction in the public funding available to the operations of the technological institutions created during the previous decades. Thus by the early 1990s, the main policy instruments available in Chile for the support of innovation and technology development were the funding of academic research carried out by around twenty five public universities and a set of technology institutes that provided business development services to a limited number of firms, mainly in connection with natural resources. It is important to say that despite the changes in the overall economic model, the actual implementation of Science, Technology and Innovation policies during the military government followed a supply-oriented approach still determined by the public sector and the academic community. This approach was clearly inspired by a linear model which assumed that knowledge was a sort of public good produced by science and technology organizations and destined to flow automatically towards the productive sector.

With the arrival of the first democratic government in the early 1990s, a new vision of the importance of science, technology and innovation for development started to emerge. In addition to recognizing the importance that technological change and innovation play in long-term economic growth, this vision also located the firm at the core of the innovation process. The result was a major shift in technology policies, putting a stronger emphasis on market incentives and designing interventions that focused on the demand side of the innovation process and on fostering the linkages among the different actors in the system. An interesting process of institutional learning then took place. Three clear phases can be identified in this development. The first phase took place under the umbrellas of the Science and Technology Program (1990-1995) and the Technology Innovation Program (1996-2000). The main focus of these programs was to support business innovation through a system of demand subsidies together with increased funding for scientific research and technological institutes. The main policy instrument during this first phase was the creation of three scientific and technology development funds that funded applied research projects led by individual academic researchers, pre-competitive collaborative university-industry projects and business innovation projects submitted by individual firms. It was during this period that FONTEC was established.[3] However, policy interventions were mainly horizontal during this first phase, supporting cross-cutting rather than sector-specific projects, which led to problems of fragmentation and lack of critical mass in many areas. Another implementation problem during this first phase was that excessive degrees of freedom were given to the main executing agencies – CORFO, CONICYT and technological institutes, among others – leading to problems of overlap and lack of coordination (see ALVAREZ et.al., 2011).

The second phase originated with the Technology Development and Innovation Program (2001-2006), whose design took advantage of the lessons learned under the previous programs by introducing an innovative institutional coordination mechanism (in the Ministry of Economics, allowing for mitigation of the lack of inter-agency coordination) and by supporting only four priority areas (biotechnology, clean production, quality certification and ICT adoption). The new program also explicitly established that support should focus on small and medium enterprises (SMEs). Thus the second phase was characterized by an increasing degree of selectivity in policy implementation. In addition to maintaining the technology funds already established, new policy interventions were designed and put in place, encouraging the systemic aspects of the innovation process and fostering the generation of spillovers. Collaborative technology development programs, such as support for sector technological consortiums and clusters, predominated in this phase.

Towards the mid-2000s it became clear that in order for the Chilean innovation system to take off it required not only the mobilization of far more resources than those invested since the early 1990s but also the solution of a series of coordina-

3 The other two funds were the National Science and Technology Research Fund (FONDECYT) and the National Fund for Scientific and Technological Development (FONDEF), both managed by the National Research Council (CONICYT). The focus of FONDECYT is on the funding of applied scientific research and, although it was created in the 1970s, its operations have expanded greatly since the 1990s. On the other hand, FONDEF's focus is the funding of collaborative R&D projects performed by public institutions and universities in collaboration with the private sector. As such it is the first really "systemic" policy instrument in Chile. A fourth fund, also administrated by CORFO, was the Innovation and Development Fund (FDI), established in 1995 to support technological infrastructure – in particular the quality accreditation system – and the development of public goods for innovation (e.g. information systems). The FDI was originally funded by changing the financial mechanism of the technological institutes. The public budget of these institutions was partially removed from direct budgetary allocations and used to fund the FDI, so that technological institutes were obliged to compete for resources, generating incentives for their closer alignment with demand for their services from the private as well as the public sector.

tion and institutional problems that remained. Indeed, since the early 1990s the process of institutional deployment had followed a "bottom-up" rationale within a context where the different executing agencies were given a high degree of autonomy. This led to the emergence of clear coordination problems with a significant level of programming overlap, together with a serious fragmentation of national innovation efforts, raising efficiency issues. The third phase of the process of institutional development originated in 2005, when in order to address these problems the government put in place a series of institutional changes aimed at fostering coordination and also at increasing public investment in the science and technology sector. The most important of these reforms were (i) the creation of the National Council for Innovation and Competitiveness (CNIC), a presidential-level organization with the mission of proposing general guidelines for a national innovation strategy and budgetary appropriations, and (ii) the establishment of the ministerial cabinet for innovation policy, in charge of implementing the strategy and aligning the different executing agencies to ensure a coherent policy mix in line with the innovation strategy. In addition, with the aim of giving more financial stability to the whole system, a new Innovation for Competitiveness Fund (FIC) was created, funded with a special tax levied on export mining. In principle, the allocation of these funds should follow CNIC recommendations. It is interesting to see how the process of institutional construction is gradually gaining momentum in the development of Chile's science, technology and innovation policies, with increasing attention over time to the institutional capacities needed for the identification, design and implementation of these policies.

Although more than five years have elapsed since these last reforms were put in place and despite some clear improvements, there is a growing consensus within the government that there is still a long way to go and that it is too early to assess the extent to which institutional changes have allowed for better coordination and improved the efficiency of public investment in science, technology and innovation. Also, there is no clear evidence that the new institutional setting has been as successful as expected with regards to the coordination of policy implementation and the coherence of the policy mix. Thus important work clearly still needs to be done to improve resource allocation and policy coordination among the implementation agencies. Coordination problems also extend beyond the organization of the different agencies within the central government to issues of multilevel governance between the central and regional (sub-national) governments (AGOSIN, et.al., 2009).

2.2. The Chilean National Fund for Technological and Productive Development: FONTEC[4]

Throughout the institutional development process described in the previous section, FONTEC has been the most important public program that provides financing for innovation projects carried out by private firms. FONTEC was established in 1991 with 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 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).

The management of FONTEC was put under CORFO and led by an Executive Board of eight members: two representatives of CORFO, one representative of the Ministry of Finance, two designated by the Ministry of Economics and three representatives of the private sector. FONTEC's operational structure included an executive director and three main departments: (i) the Operations Department, which managed the selection and evaluation process, negotiated contracts with clients, and followed up project execution; (ii) the Legal Department, which was mainly involved with drafting of contracts and assessment of guarantees; and (iii) the Administration Department, which handled disbursements and other administrative matters. FONTEC had around 25 staff, most of whom were engineers. In addition, FONTEC was supported by some external organizations under contract. In order to encourage business innovation, FONTEC implemented a series of co-funding mechanisms that stimulated a wide variety of projects, including business R&D, technology transfer activities and the gestation of new technological infrastructure. More specifically, in the period analyzed FONTEC operated five lines:

Line 1 – Technological innovation: It financed R&D projects aimed at developing new products and improving production processes. It covered the development of prototypes and market testing. The FONTEC subsidy never exceeded 50% of total costs.

Line 2 – Technological infrastructure: It financed investment in physical infrastructure, installation and equipment, as well as the training of firm staff involved in

4 This section builds on Benavente J.M. and J.J. Price (2009).

the development of this infrastructure. The co-financing limit ranged between 20% and 30%, depending on whether the investment was submitted by a single firm or a group of firms.

Line 3 – Group transfer: It supported projects submitted by a group of at least five firms and it covered the cost of technological missions abroad, training and technical assistance by highly specialized international experts. The co-financing limit was fixed at 45% for technological missions and 50% for specialized consultants. In any case the amount of funds granted by FONTEC was never higher than US$100,000.

Line 4 – Technology transfer organizations: It financed projects submitted by groups of at least five firms with the aim of setting up a technology transfer center to study, develop, diffuse and adapt technology. The maximum subsidy was equal to 50% of the investment and not higher than US$400,000.

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

Table 1 presents a summary of FONTEC operations for the period 1991-2004. Overall, FONTEC supported a total of 5,606 firms, providing funding for about 2,500 projects. However, most of the firms were assisted through technology transfer line 3 – mostly technological missions and consultancy. This line represented a little more than 10% of investment by the program. On the other hand, the most important line in terms of resources was technological innovation one (Line 1), which supported around 1,300 firms for a total of 1,784 R&D projects and absorbed around 80% of total public investment in the fund. Given its importance, Line 1 is the focus of this impact evaluation.

The co-funding requirement was certainly one of the most important characteristics of the program across all its lines. The matching grants instrumented by FONTEC are a type of *direct support* for business innovation which is *project-specific*. Thus they modify the firms' marginal cost of financing and may raise the private marginal rate of return on the innovation investment by, for example, inducing collaboration with other actors with complementary assets. Given the problem of information asymmetry between the public agency and the beneficiary, direct subsidies might suffer from opportunistic behavior and moral hazard problems. Indeed while the public agency might want to maximize firms' innovation efforts, private entities might aim at maximizing the size of the innovation project (and of the subsidy).

However, the moral hazard problem implicit in a direct subsidy could be controlled for, if not fully eliminated, by a design that considers a *matching grant* approach with *maximum* limits and a list of eligible expenses. In other words, the subsidy never covers the full costs of the supported project. It is expected that by using this approach there will be a better alignment between the goals of the public agency and the firm, somehow controlling for the potential problem of moral hazard. In other words, if the beneficiary wants to increase the size of the innovation project in order to extract a higher subsidy, it will also have to pay a higher cost. Additionally, the operation of the co-funding mechanisms is normally implemented through the ex-post reimbursement of the approved expenditures that qualify for the subsid.

TABLE 1
Projects, beneficiaries and funds by line of financing – 1991-2004

Variables	N. projects	N. Firms (1)	Total value (2)	FONTEC (2)	Line / tota (%)l	Firms (2)
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***
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**

Source: Authors' elaboration on the basis of CORFO and Dini and Stumpo (2002).
(1) Information available up to 2001.
(2) USD.

However, the above-mentioned counterbalances come at some cost. The main problem with the direct subsidy schemes is that they need important institutional capacities in the executing agency and when these capacities are not present the efficiency of the whole operation dramatically decreases. The building of these capabilities requires that two additional conditions need to be met: first, the system needs to be quite predictable in order to allow for policy experimentation, monitoring and evaluation to take root; second, some critical mass of human capital in the executing agency and the support system needs to be available (evaluators, peer reviewers etc).[5] A second problem with matching grants is that as subsidies are paid ex post against receipts, they do not seem to be very suitable for the promotion of entrepreneurship. Indeed, if it is the case that the (new) entrepreneur is credit constrained, this type of funding may be of little help. Some designs are trying to correct for this through the inclusion of advance funding provisions for new firms, but even in this case this advance cash needs to be covered by guarantees.[6] A third problem when direct subsidy schemes are implemented in weaker contexts is that their success depends on the firm's ability to identify an innovation opportunity that can be codified into a coherent project proposal. The presence of these sorts of capabilities on the demand side of the scheme is not something that can be taken for granted. Overall, the FONTEC matching-grants system subsidized 38% of the total value of the supported innovation projects across all the lines. However, consistent with the idea of capacity building, both in the managing institution and the firms, the share of co-funding from the private sector systematically increased over time. Indeed, while in 1992 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, remaining at this level thereafter.

With regard to Line 1, the number of projects supported varied between 128 in 2002 and 215 in 1999. Little more than 50% of the supported projects came from the manufacturing sector and 18% from agriculture. Very little participation is observed by the service and general purpose technology sectors (Table 2). Additionally, about 60% of all the projects supported under Line 1 were located in the metropolitan region of Santiago, while just 8% of the projects corresponded to the

5 When these capacities are not met, the outcome might be high administration costs. This is very clear at the early stages of policy experimentation when it is not uncommon to find that hurdles to apply are high, the speed at which applications are processed are too slow and the opportunity costs of applying are prohibitive, particularly in the case of SMEs and start-up firms.

6 An important caveat here is that if public agencies act as a screener, conveying the technical knowledge that the financial markets lack or are not willing to develop, they should also reduce the usual problem of information asymmetry between external financiers and innovative firms. In this way, subsidies based on externally and technically evaluated projects might "signal" a good innovation idea that might later on be funded by the financial markets (more on this in the next section) (Lerner, 1999).

second region in importance (Concepcion). This result is to be expected, given the regional neutrality of the program and the fact that Chile's technological capacities are strongly concentrated in Santiago.

TABLE 2
Line 1: Supported projects by main economic sector – 1991-2004

Sector	Projects	%
Agriculture	323	18.1
Fishing	77	4.3
Mining	52	2.9
Manufacturing	937	52.5
Utilities	5	0.3
Construction	59	3.3
Transport and Communications	45	2.5
Trade	14	0.8
Financial Services	25	1.4
Other Services	98	5.5
Biotechnology	112	6.3
Environment	37	2.1
Total	**1 784**	**100.0**

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

FONTEC was formally terminated in 2005 when it was merged with other funding instruments also managed by CORFO (the FDI). This decision was taken not only to increase operational efficiency, but also to coordinate better the different lines of FONTEC (aside from Line 1), with technology transfer activities being funded by FDI to reduce duplication and overlap. The decision was also taken to give the funding instruments a higher degree of selectivity consistent with the overall change in the emphasis of innovation policy in the mid-2000s. Both funds were merged under a new organizational unit of CORFO called INNOVA CHILE, with four areas of intervention: public interest and pre-competitive research, business innovation, diffusion and technology transfer, and entrepreneurship. Additionally, the approval of the Innovation Fund for Competitiveness (IFC), funded by a new tax on copper exports, allowed for a substantial increase in the budget of INNOVA CHILE. The learning accumulated during FONTEC was critical for the deployment of INNOVA CHILE and the operation of Line 1 continued under the new name of business innovation. In total 436 business innovation projects were funded by the continuation of Line 1 during the period 2006-2009, with a level of co-funding similar to the level seen under the previous organizational setting. In summary, the main features of FONTEC's Line 1 continued during the operations of INNOVA CHILE (at least until 2009). However, one important achievement of the new operation was an increase in funding allocated to the regions, which under INNOVA CHILE obtained a share of funding similar to the metropolitan region of Santiago. The evaluation in this paper focuses on the period 1997-2006, before these changes took place.

2.3. 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.[7] Market failures arise for four main reasons: (i) incomplete appropriability of innovation rents; (ii) information asymmetry 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 guarantees 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.[8] Therefore, the 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 significant information asymmetry between lenders and borrowers on technical contents of innovation

7 See, for example, Levin et al. (1987), Mansfield et al. (1981) and Martin and Scott (2000).

8 Knowledge goods cannot practically be withheld from one individual consumer without withholding them from all (the 'non-excludability criterion'), and the marginal cost of an additional person consuming them, once they have been produced, is zero (the 'non-rivalrous consumption' criterion).

projects seriously limits the possibility of obtaining 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.[9] However, the argument may not be so relevant for large and established firms, which are less likely to be financially constrained.

Some evolutionary scholars complement this market-failure approach by arguing that public intervention should also address the dynamic, collective, uncertain and discontinuous nature of the innovation process.[10] This implies that public intervention is not only justified in conventional cases of 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 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 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.[11]

Lines 1 and 2 of FONTEC were originally designed to deal with the problem of financial constraints that affect many business innovation projects. The original design was that of a conditional loan: if the supported project was successful, then the loan would be fully repaid by the firm, in proportion to the total profits generated by the project. If the project failed to produce the expected results, the firm would be entitled to convert the loan into a subsidy. 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.[12] Thereafter, both lines adopted a matching-grant mechanism, which reduced the administrative cost of the provision of public funds and facilitated the mobilization of private resour-

9 See for example Klette and Moen (1999), Hall (2002) and Duguet (2004).

10 See Nelson and Winter (1982), Dosi et al. (1988), Dosi and Nelson (1994), Metcalfe (1994), Cimoli and Dosi (1995) and Teubal (1998).

11 According to the "network of learning" approach (POWELL et al., 1996) and the "interactive learning" approach (LUNDVALL, 1988 and 1992; Morgan, 1996), networks facilitate organizational learning and act as a locus of innovation. Thus, "organizational learning is a function of both access to new knowledge and the firm's capabilities of utilizing and building on such knowledge" (POWELL et al., 1996: 118).

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

ces for innovation.[13] Thus over time the lines became more typical of solutions to imperfect appropriability problems, in addition to liquidity constraint problems. Liquidity constraint problems were addressed both directly, through funding, and indirectly, through the signaling effect of screening good innovation projects via the implementation agency. This process could contribute to reducing the asymmetry of information between the financial sector and the innovative firm and fill the information gap between borrower and lender (LERNER, 1999). Some evidence of the importance of this signaling effect is provided by interviews with firms. Indeed, 50% of the firms applying to FONTEC did so in order to get access to complementary financing, 30.6% because FONTEC was a fundamental source of financing (since the project had been rejected by the private sector) and 27.9% because FONTEC financing provided a signal of the quality of the project outside the firm. Only 26% of the firms applied because they wanted to share the risk of being copied by competitors (BENAVENTE et.al., 2007).

Lines 3 and 4 of FONTEC aimed at taking advantage of the benefits of joint ventures and alliances in developing innovations. The rationale for this type of intervention is twofold. First, it aims at reducing the typical duplication problem of private investment in R&D, a problem that often emerges when cooperation between firms is not allowed or supported. Second, research collaboration might allow better appropriation of innovation rents, leading private investment closer to its social optimum. Additionally, Line 4 also aims to support 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 in the shape of public or semi-public goods, such as highly specialized laboratories and equipment.

The focus of the current evaluation is on the impacts of projects funded by FONTEC's Line 1 – the technology innovation line – and so we expect the impacts to be mainly on innovation efforts (if the line is successful in reducing information asymmetries and appropriability problems). In principle, we do not expect high impacts on other systemic indicators such as the formation of consortiums or research collaboration, as these are not the targets of Line 1. However, as some firms indicated in interviews, some effect on collaboration could be expected through the role FONTEC's project officers played during the monitoring phase of the projects, for example, by giving advice on knowledge and technical assistance providers.

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

3. Empirical strategy and data

3.1. FONTEC's expected impacts

As is clear from the above discussion, although innovation policies might be justified because of the presence of many different markets and coordination difficulties, successful implementation strongly depends on governments' ability to rectify the identified failures. In real life, governments face informational constraints that may be as or more severe than those of firms. Firms and innovation projects are highly heterogeneous. This means that a policy that is optimal in the strict sense of achieving Pareto efficiency should vary not only from firm to firm, but also from project to project. This puts administrating agencies under severe informational stress (TOIVANEN, 2009). In summary, although there might be a strong case for innovation policies, actual implementation could easily lead to the wrong results or in other words public support could lead to crowding-out of private funding.

One of the first issues to be defined in an impact evaluation is how and when to measure the effects of the program, i.e. the outcomes of interest. In the spirit of the CDM model (CRÉPON; DUGUET; MAIRESSE, 1998), a distinction can be made between innovation-input indicators and economic-performance indicators. Innovation-input indicators are the indicators most directly affected by the intervention. For instance, for a tax incentive program, an innovation-input indicator is total investment in innovation by the beneficiary. While the relationship between the subsidy and total investment seems in principle almost tautological, our previous discussion clearly highlights that this is not necessarily true (see e.g. DAVID; HALL; TOOLE, 2000). In other words, to the extent that innovation policy is capable of changing the firm's marginal capital cost and to the extent that investment decisions react to this we might be capable of identifying the extent to which innovation policies generate *input additionality*. So, in the context of the current evaluation we will focus on the following indicators to measure input additionality:

- Innovation expenditures to sales.
- R&D expenditures to sales.
- Proportion of R&D in innovation expenditures.
- Privately financed R&D expenditures to sales.
- Proportion of R&D outsourced to other actors of the innovation system.

The first indicator captures the overall innovation effort by the firm, which includes R&D but also expenditures on training, know-how, software development and adoption of embodied technology. The second indicator focuses on R&D expenditures, the type of investment that is targeted by FONTEC's Line 1. The third indicator is an alternative way of measuring R&D efforts, which is as a proportion of the total innovation effort. We used this alternative indicator because, being a fraction in the (0-1) interval, it has a lower variance than the second one. The fourth indicator is R&D which is privately financed: this indicator identifies crowding-in/-out effects. Finally, the fifth indicator captures the fraction of R&D which is subcontracted to other actors of the Chilean innovation system, so that this indicator is well positioned to capture any impacts on interaction.

However, just assessing whether innovation efforts increase as a consequence of a subsidy is not enough for policy evaluation purposes. The whole portfolio of innovation projects held by the firm is normally affected as a result of any policy intervention. As a result of this, projects with different productivity might be executed while others might be postponed. Thus assessing the outputs of innovation investments is also important (*output additionality)*. Innovation outputs are variables where the concrete realization of innovation activities and their impacts on economic performance are observed. We therefore inspected the following variables in order to track any evidence of *output additionality*, especially in the case of business innovation programs such as FONTEC:

- Employment.
- Skills.
- Labor Productivity.
- Total Factor Productivity.

In principle, employment can be considered a proxy for firm growth; however, an additional reason to explore this relationship is because in the case of innovation, impacts on employment cannot be straightforwardly predicted due to the presence of both substitution and compensation effects (VIVARELLI, 2011). The impacts of innovation on employment might be different for employees with different skills. In this case, due to the lack of good information on skills in the Chilean data, we use as a proxy the average real salary of the workforce. Finally, it is expected that innovation could lead to more efficient technologies or better quality products; both should show up in productivity growth. We therefore use two indicators for this variable: labor productivity, which requires fewer assumptions in terms of technology but is contaminated by variations in inputs, and total factor productivity, which is more closely aligned with the idea of knowledge generation.

We close this section with a short discussion of the issue of when impacts should be measured. Normally, input additionality is measured in the short term, which is while the innovation project is being implemented. However, in the case of output additionality a "time to build" period is necessary to find impacts. More generally, the impacts of different programs may display very different patterns over time. An intervention may generate a one-shot increase in outcomes or may have strong impacts that fade out progressively with time; the impact of a program may only appear after a certain period, or may even generate an initial drop in outcomes that is later overshot by increases in subsequent years. As a result, a proper consideration of the timing of the effects is crucial in an impact evaluation setting, and failure to account for these issues may lead to misleading conclusions and policy recommendations. A clear distinction should be made between short-run and long-run effects to assure proper evaluation of the costs and benefits of a public program. Thus in the case of the current evaluation, while we measure input additionality in the short term, in measuring output additionality we follow the indicators over a long time period.

3.2. Estimation strategy

Evaluating the impacts of public programs such as FONTEC is not a trivial task, especially when the interpretation of the relationship between program participation and the outcomes of interest is to be causal. In impact evaluation, the main definition of causality is based on the concept of *counterfactuals*. For instance, suppose a firm receives a subsidy for innovation investment, and suppose we observe the value of a given outcome of interest for that firm. Then, the public subsidy is said to have a causal effect if the outcome of the firm in the absence of subsidy, but *holding everything else equal*, would have been different. In other words, the program or "treatment" has a causal effect if the observed outcome when the firm receives a subsidy is different from the *counterfactual outcome*, i.e. the outcome that would have been observed if the firm did not receive the subsidy. While this definition of causality is relatively simple and intuitive, it introduces a serious problem from an empirical point of view, because the counterfactual outcome, by definition, is never observed. In other words, if a firm receives a subsidy, it is impossible to know with certainty how this firm would have done it without it. This problem can be approached by setting a control group of firms that did not receive support from the program selected, in such a way as to minimize all the observable differences among both groups. Thus our estimation strategy was based on comparing treated and non-treated firms.

Propensity Score Matching (PSM) is a procedure to generate sub-samples of firms that are similar in several dimensions based on information obtained directly from the data 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:

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

Where D={0,1} is the indicator of exposure to treatment and X is a multi-dimensional 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:

$$\tau = E\left[E\left(Y_1 \mid D=1, p(X)\right) - E\left(Y_o \mid D=0, p(X)\right) \mid D=1\right] \quad (2)$$

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 (2) provides for an unbiased estimator of impacts under the assumption that observations with the same propensity score have the same distribution of observable characteristics independently of treatment status (the balancing of observables property). 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 (2)) is given by:

$$\hat{\tau} = \frac{1}{n_T} \sum_{i \in T} \left\{ Y_{i1} - \sum_{j \in C} W_{ij} Y_{j0} \right\} \quad (3)$$

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 probit model where the binary dependent variable reflects the firm's participation in the program. Pre-program participation levels of input or output indicators together with other covariates were used to estimate the model. 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 their participation in the program started.

For the output indicators we had access to a large cross-section time-series database. In this case, the panel structure allows us to exploit between- and within-firm variability to estimate the impact of FONTEC. An attractive feature of this is that it allows controlling for unobserved heterogeneity. Assuming this heterogeneity is constant over time, some types of potential selection biases can be mitigated using a fixed effects model. More precisely, we ran the following specification:

$$Y_{it} = \alpha_i + \lambda_t + \tau D_{it} + \varepsilon_{it} \quad (4)$$

where Y_{it} is the outcome of firm *i* in year *t*, and D_{it} is a treatment indicator variable defined as a binary variable taking the value one from the first year of participation to the end of the period. Under this specification, tau estimates the average impact of the program over the whole period of participation.

The individual fixed effects α_i capture all the factors (both observed and unobserved) affecting the outcomes that vary across firms but are fixed over time, and λ_t is a time effect (modeled as a set of year dummies) which affects all firms in the same way. Finally, ε_{it} is the usual error term. The standard-error estimators will be clustered at the firm level to account for the possibility of correlation of errors within firms. Assuming time-constant unobserved heterogeneity (which is equivalent to stating that the trends in outcomes between treated and untreated groups are parallel before the program), regressions (3) and (4) should result in consistent estimators of the impact of the program, but the identification assumption is less likely to be met if the groups of treated and untreated firms are very heterogeneous and thus may differ in unobserved time varying factors. To mitigate the impact of this kind of bias, we ran regressions (3) and (4) for a match sample of firms selected using the matching method described above. In other words we combined the fixed effects method with the PSM approach.

3.3. Description of the data

For this research we used two sets of data. The first set corresponded to the National Technological Innovation Survey (ENIAT) 2005, consisting of cross-sectional data with information on innovation inputs (innovation investments, R&D and financing) for years 2003 and 2004. Although there were other innovation surveys in Chile before 2005, by methodology the different ENIATs are not panel datasets, so that selected samples substantially change among different waves of each survey. Only a relatively small fraction of firms can be followed over time (only for some years). Given this limitation, we used ENIAT 2005 to measure input additionality only, or short-term impacts. Another reason to use ENIAT 2005 was that it was the first survey that asked about the use of FONTEC among sources of financing for innovation activities. Finally, in order to keep consistency with the output dataset, we worked only with the sub-sample of ENIAT 2005 that corresponded to manufacturing firms and also eliminated from the working dataset those firms that were supported by FONTEC in 2003. Thus we worked only with first-time treated firms in 2004. This allowed us to use information for 2003 as a baseline for estimation of the PSM. In total, there were little more than 1,000 observations in the dataset.

The second dataset was the National Annual Manufacturing Survey (ENIA) for the period 1995-2006. This dataset had a sample size of about 5,000 firms per year, and in practical terms was a census of all manufacturing firms with 10 or more employees. We used administrative data provided by INNOVA CHILE and the collaboration of INE in order to identify those firms in ENIA that were beneficiaries of FONTEC (Line 1) during the period concerned. For estimation, we used only the years 1998-2006 and deleted all beneficiaries supported by FONTEC before 1998 in order to have baseline information from the pretreatment phase with which to find suitable matches for firms supported after 1998.

4. Empirical results

4.1. Input additionality: testing for crowding-in and crowding-out effects

We start by describing the main descriptive statistics for ENIAT 2005. Table 3 shows that Chile is no exception to the rule for Latin America in terms of the innovation efforts carried out by firms. Indeed, total innovation expenditure for the average firm was just over 2% of sales. In terms of R&D, the graphs were even lower, with expenditure averaging 0.5% of sales in 2004. However, there was a slight increase in both graphs from 2003. On average, about 90% of total innovation expenditure was privately funded, while about 4% was subcontracted to external institutions. In terms of the other covariates, we found that about 10% of the firms were foreign owned, while almost 60% were located in Santiago's metropolitan area. About 36% of the firms were exporters in 2003. In terms of production structure, 21% of the firms operated in natural resource processing industries (such as foodstuffs, beverages, and pulp and paper), while 31% were in labor-intensive sectors (textiles, clothing, wood and furniture), 32% in scale-intensive sectors (such as chemistry, ceramics, glass and steel), and just 15% in skills-intensive sectors (such as machinery and equipment, computing and transport equipment). Finally, the typical firm was 25 years old. Among these firms, after checking for inconsistencies in firms' reporting, we found that 7% of the firms (80 observations) were beneficiaries of FONTEC in 2004 but not in 2003. We eliminated those firms that were beneficiaries of FONTEC also in 2003 and those firms that reported being beneficiaries from FONTEC but did not report any subsidy from government for in-house R&D (FONTEC was the only program supporting this type of investment in Chile at that time).

With the above variables, we estimated the propensity score (i.e. the probability of participation) for each firm in the sample. We estimated a probit model for program participation as a function of pre-program innovation efforts and R&D expenditures, together with a long list of control variables and sectorial dummies. All the control variables were set for their values in 2003. The results of the probit model can be inspected in the appendix. After estimating the propensity score, we proceeded with matching. Several matching algorithms are available, but in this paper we use k-nearest neighbor matching with k=5. Thus for each beneficiary firm we selected the 5 closest firms from the control group based on the distance measured by the propensity score. The results are robust to different algorithms (in particular to variations of k and use of kernel matching).

After matching, we proceeded to test the extent to which we were able to balance the characteristics of the beneficiaries and the control group in 2003, in other words before participation. The results of the tests are summarized in Table 4. Inspecting the results in the table is also important in order to detect systematic differences between treated and untreated firms, since these differences reveal the selection mechanisms used by FONTEC.

TABLE 3
Descriptive statistics ENIAT 2005

Variables	OBS	MEAN	STD	MIN	MAX
Innovation Activities to Sales 2003	1118	0.0174	0.0604	0.0000	0.8687
Innovation Activities to Sales 2004	1118	0.0201	0.0726	0.0000	0.8073
R&D to Sales 2003	1118	0.0041	0.0247	0.0000	0.4608
R&D to Sales 2004	1118	0.0052	0.0346	0.0000	0.7568
Fraction of R&D in Innovation 2003	1118	0.1113	0.2545	0.0000	1.0000
Fraction of R&D in Innovation 2004	1118	0.1148	0.2517	0.0000	1.0000
Private R&D to Sales 2004	1118	0.0050	0.0343	0.0000	0.7568
Private R&D to Sales 2003	1118	0.0041	0.0247	0.0000	0.4608
Contracted R&D 2003	1118	0.0405	0.1683	0.0000	1.0000
Contracted R&D 2004	1118	0.0458	0.1791	0.0000	1.0000
Participation in FONTEC	1118	0.0716	0.2579	0.0000	1.0000
Employment 2003 (LN)	1118	4.0189	1.3971	0.0000	7.9420
Labor Productivity 2003 (LN)	1118	10.5187	1.3969	5.5360	18.0399
Dummy if Exporter in 2003	1118	0.3694	0.4829	0.0000	1.0000
Dummy if Natural Resource Sector	1118	0.2120	0.4089	0.0000	1.0000
Dummy if Labor-Intensive Sector	1118	0.3247	0.4685	0.0000	1.0000
Dummy if Scale-Intensive Sector	1118	0.3122	0.4636	0.0000	1.0000
Dummy if Skills-Intensive Sector	1118	0.1512	0.3584	0.0000	1.0000
Dummy if Foreign-Owned	1118	0.1038	0.3051	0.0000	1.0000
Dummy if Located in Santiago	1118	0.5966	0.4908	0.0000	1.0000
AGE	1118	25.5170	23.4566	0.0000	194.0000

Source: Authors' elaboration using ENIAT 2005 and CORFO.

The results in Table 4 suggest that a simple unmatched comparison between beneficiaries and untreated firms is misleading because there is a set of variables where FONTEC firms are systematically different from the control group. In particular, the FONTEC program tended to select firms with above-average capabilities. Moreover, FONTEC firms on average had higher rates of innovation investment, higher R&D expenditure, a higher proportion of R&D in total innovation investment, and a higher share of collaborative research. FONTEC firms were also larger, and a higher proportion were exporters and came from skills-intensive sectors. However, after matching we did manage to balance all these variables on average. Indeed, as the last column of Table 4 indicates, there were no longer any statistically significant differences between the two samples after matching.[14] At the bottom of Table 4, we show an omnibus test for the overall balance among the two samples.

Graph 1 overlays propensity scores for treated and control firms in the matched sample. The results suggest that both FONTEC and control group firms had the same probability of receiving support from FONTEC. In other words, after the matching we end up dealing with comparable firms.

The impact results are summarized in Table 5. Results are presented in two panels. The top panel shows the impacts on the main input variables in 2004, measured in levels. The bottom panel shows the results for the same variables measured in first differences. Measuring in first differences controls for unobserved (fixed) omitted factors. The results show the following:

- There is an increase in total innovation efforts. Indeed, innovation investment rates for FONTEC firms are systematically higher than innovation rates for the control group (6% vs. 3%) and this result is significant at a 10% level.
- There is also an increase in R&D efforts by the FONTEC firms in comparison with the control group. Indeed, while R&D investments amounted to 30% of total innovation efforts for the FONTEC firms, the proportion was only 20% for the control group firms. This difference is statistically significant as well.
- We also found that FONTEC firms allocated a larger share of R&D efforts to subcontracting R&D from other innovation actors. The ratio of subcontracting was 12% for the FONTEC firms and only 6% for the control group. This difference is statistically significant at 10%.
- Finally we did not find any statistically significant evidence that private financing of R&D investment was higher in FONTEC than the control group. Private financing for R&D was 1.4% of sales for FONTEC firms, while the proportion for control firms was 0.8%. The difference, although positive, is not significant. Thus there is no evidence that FONTEC subsidies were crowding out private financing, but there is also no evidence in favor of crowding-in.

14 An omnibus test for the overall balancing of the two samples which is statistically significant for the unmatched sample (Pseudo R2=0.085, LR-Chi2=49.17, P=0.00) is no longer significant for the matched sample (Pseudo R2=0.01, LR-Chi2=4.45, P=0.99)

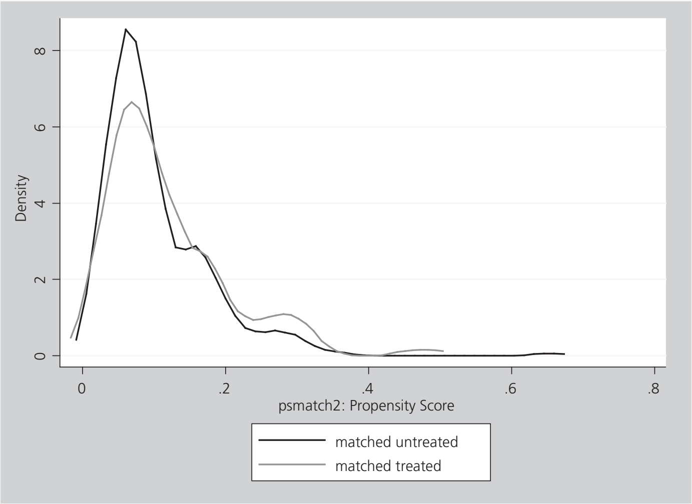
TABLE 4
Balancing test matching ENIAT 2005

Variable	Sample	Treated	Control	t	P>|t|
Innovation Activities to Sales 2003	Unmatched	0.04	0.02	3.69	0.00
	Matched	0.04	0.04	0.25	0.80
R&D to Sales 2003	Unmatched	0.01	0.00	1.95	0.05
	Matched	0.01	0.01	0.08	0.94
Fraction of R&D in Innovation RD03	Unmatched	0.23	0.10	4.35	0.00
	Matched	0.23	0.22	0.34	0.73
Contracted R&D 2003	Unmatched	0.07	0.04	1.52	0.13
	Matched	0.07	0.06	0.41	0.69
Age	Unmatched	29.44	25.22	1.55	0.12
	Matched	29.44	27.84	0.57	0.57
Foreign-Owned	Unmatched	0.06	0.11	-1.26	0.21
	Matched	0.06	0.07	-0.38	0.71
Located In Santiago	Unmatched	0.59	0.60	-0.17	0.86
	Matched	0.59	0.51	1.57	0.12
Employment 2003 (LN)	Unmatched	4.46	3.99	2.92	0.00
	Matched	4.46	4.50	-0.34	0.74
Employment 2003^2 (LN)	Unmatched	21.59	17.83	2.65	0.01
	Matched	21.59	22.05	-0.35	0.72
Labor Productivity 2003	Unmatched	10.72	10.50	1.34	0.18
	Matched	10.72	10.75	-0.20	0.84
Exporter 2003	Unmatched	0.58	0.35	3.98	0.00
	Matched	0.58	0.56	0.24	0.81
Natural Resource Sector	Unmatched	0.19	0.21	-0.56	0.58
	Matched	0.19	0.17	0.43	0.67
Labor-Intensive Sector	Unmatched	0.24	0.33	-1.73	0.08
	Matched	0.24	0.25	-0.28	0.78
Scale-Intensive Sector	Unmatched	0.34	0.31	0.51	0.61
	Matched	0.34	0.35	-0.15	0.88
Skills-Intensive Sector	Unmatched	0.24	0.14	2.24	0.03
	Matched	0.24	0.24	0.06	0.96

Source: Authors' elaboration using ENIAT 2005 and CORFO.

GRAPH 1

Propensity score distribution, treated and control firms, matched sample. ENIAT 2005



Source: Authors' elaboration using ENIAT 2005 and CORFO.

TABLE 5

Impact results ENIAT 2005

Variable	Treated	Control	Difference	Z	P>|Z|
Innovation Activities to Sales 2004	0.063	0.031	0.031	1.72	0.09
R&D to Sales 2004	0.016	0.008	0.008	1.24	0.21
Fraction of R&D in innovation 2004	0.323	0.200	0.123	2.76	0.01
Private R&D to Sales 2004	0.014	0.008	0.006	0.90	0.37
Contracted R&D 2004	0.120	0.066	0.054	1.65	0.10
Variables in Difference					
Innovation Activities to Sales 04-03	0.021	-0.007	0.029	1.60	0.11
R&D to Sales 04-03	0.007	-0.001	0.008	1.51	0.13
Fraction of R&D in innovation 04-03	0.093	-0.017	0.111	2.53	0.01
Private R&D to Sales 04-03	0.005	-0.001	0.006	1.08	0.28
Contracted R&D 04-03	0.052	0.006	0.046	1.62	0.11

Source: Authors' elaboration using ENIAT 2005 and CORFO

4.2. Evaluation of the output additionality of the program

In this section we present the results for output additionality. We measured these results by looking at four different impact indicator variables: (i) employment, (ii) real salaries per employment, (iii) labor productivity (value added per employment) and (iv) total factor productivity.[15] For each one of these indicators we report three set of results: (i) simple (OLS based) comparisons between the treated and control groups, the so called naïve estimator, (ii) fixed effects estimates, and (iii) fixed effects and propensity score matching results.

As mentioned above, the main dataset for this analysis is ENIA 1995-2006. This dataset has a sample of little more than 5,000 manufacturing firms per year. The dataset does not have information on FONTEC participation, however. With the collaboration of INE, we managed to identify which firms were beneficiaries of FONTEC. In total, we obtained 1,154 observations corresponding to firms that participated in FONTEC during the period 1997-2006. The actual number of beneficiary firms is 234, each of which was followed on average over a five-year period. We eliminated those firms that also participated in the period 1995-1997 in order to have enough baseline information for the estimation of the propensity score.

The starting point of the analysis was the exploration of the propensity score results. This allowed us to understand the differences between FONTEC beneficiaries and non-beneficiaries before participation, as well as the determinants of enrollment in the program. For each FONTEC firm that started to participate in 1997 or later, we used two years of pretreatment values of the main output variables together with other control variables in order to predict its participation probability. The control sample comprised those firms that never participated.[16] The sample for the participation model is a pooled cross-section time-series sample. Table 6 shows the differences among the key predictors of participation, all of them measured before participation for both the matched and unmatched samples.

15 Real salaries were obtained by deflating nominal salaries using the consumer price index. Normal variables used to compute the two indicators of productivity were deflated using 3-digit sector manufacturing deflators provided by INE. Finally, in order to compute total factor productivity we used output elasticities obtained from Alvarez and Crespi (2007).

16 Actually ENIA is a plant-level survey. However, less than 8% of the plants in the case of ENIA correspond to multi-plant firms. These plants were aggregated to a firm-level indicator before merging the dataset with the sample of beneficiaries.

TABLE 6
Balancing test matching ENIA 1997-2006

Variable	Sample	Treated	Control	t	P>ltl
Santiago	Unmatched	0.679	0.528	4.570	0.000
	Matched	0.679	0.685	-0.210	0.835
Export (t-1)	Unmatched	0.529	0.236	11.680	0.000
	Matched	0.529	0.526	0.100	0.922
Labor (t-1)	Unmatched	4.211	3.597	9.140	0.000
	Matched	4.211	4.230	-0.280	0.781
Labor (t-2)	Unmatched	4.203	3.594	9.060	0.000
	Matched	4.203	4.215	-0.180	0.859
Skills (t-1)	Unmatched	7.717	7.449	6.750	0.000
	Matched	7.717	7.738	-0.690	0.488
Skills (t-2)	Unmatched	7.706	7.435	6.720	0.000
	Matched	7.706	7.731	-0.780	0.436
Lab Prod (t-1)	Unmatched	8.673	8.326	5.420	0.000
	Matched	8.673	8.702	-0.550	0.584
Lab Prod (t-2)	Unmatched	8.645	8.327	4.860	0.000
	Matched	8.645	8.679	-0.630	0.528
TFP (t-1)	Unmatched	-0.036	0.008	-4.280	0.000
	Matched	-0.036	-0.027	-0.670	0.501
TFP (t-2)	Unmatched	-0.062	0.009	-4.150	0.000
	Matched	-0.062	-0.051	-0.650	0.519
Natural Resource	Unmatched	0.320	0.363	-1.310	0.191
	Matched	0.320	0.347	-0.970	0.331
Labor-Intensive	Unmatched	0.091	0.269	-5.890	0.000
	Matched	0.091	0.078	0.820	0.410
Scale-Intensive	Unmatched	0.283	0.179	3.910	0.000
	Matched	0.283	0.278	0.200	0.838
Skills-Intensive	Unmatched	0.306	0.189	4.340	0.000
	Matched	0.306	0.298	0.300	0.765

Source: Authors' elaboration using ENIA 1997-2006.

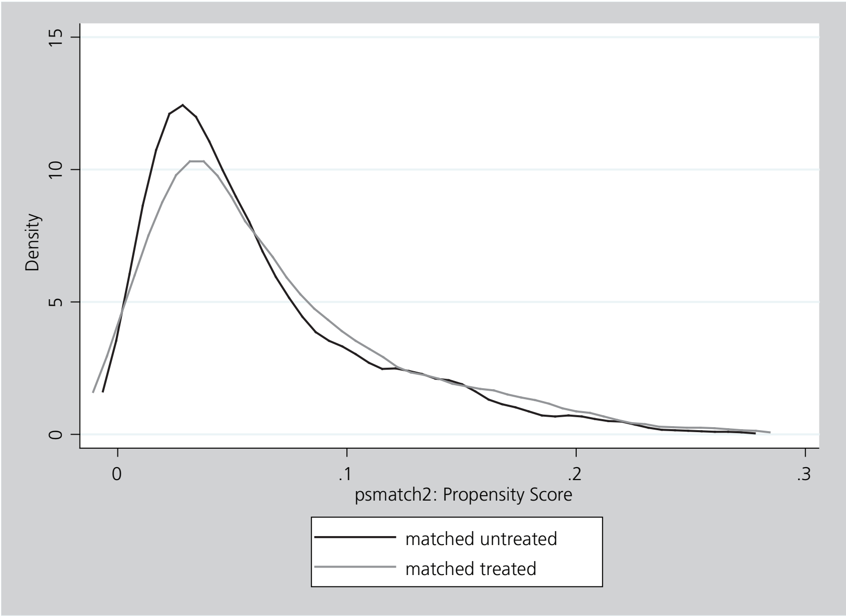
The results in Table 6 show that firms located in Santiago were more likely to be selected for FONTEC. Also being an exporter made the firm more likely to participate in the program. On the other hand, the program showed a bias towards scale-intensive and skills-intensive economic sectors. In terms of the pretreatment output variables, the results were as follows. Beneficiaries were larger than non-beneficiaries and also more skills-intensive (paying higher salaries). Consistent with this result, beneficiary firms achieved higher labor productivity on average than non-beneficiaries. However, in terms of total factor productivity FONTEC firms displayed lower average pretreatment productivity than non-beneficiary firms. Thus firms participating in FONTEC appear to have been those that on average had high capabilities (in terms of skills, technological intensity of the sector of origin and exports) and labor productivity, but low total factor productivity. This combination of high potential capabilities and poor productivity explains why these firms were willing to apply for FONTEC grants.

Table 6 also shows that the procedure very successfully balanced the different characteristics of participant firms and control group firms. Indeed, as can be seen from the matched sample row of the table, there are no longer statistically significant differences between the key variables for the two groups of firms. These results are also confirmed by an omnibus test of the balancing property.[17] Finally, Graph 2 shows the distribution of propensity scores across the two samples, which also suggests that both samples are very well balanced.

Table 7 shows the results for the output indicators. The OLS (biased) results are provided as a benchmark. They suggest that FONTEC led to an increase in all the output indicators. Impact growth rates were high, perhaps too high to be true: 65% for employment, 30% for skills, 35% for labor productivity, and only 3% for total factor productivity. The middle panel of Table 7 shows the results for the fixed effects model. There was a dramatic reduction in all the impact indicators, suggesting that a great deal of the previous findings were biased due to the presence of unobserved, i.e. fixed heterogeneity. Indeed, there was a positive and significant effect on employment (9%) and labor productivity (7%), but we did not find any effects of skill. On the other hand, there was positive and significant growth in total factor productivity (9%).

17 An omnibus test for the overall balancing of the two samples which is statistically significant for the unmatched sample (Pseudo R2=0.11, LR-Chi2=230.72, P=0.00) is no longer significant for the matched sample (Pseudo R2=0.00, LR-Chi2=4.38, P=0.98)

GRAPH 2
Propensity score distribution, treated and control firms, matched sample. ENIA 1997-2006



Source: Authors' elaboration using ENIA 1997-2006.

The bottom panel of Table 7 shows the results for the fixed effects model when the control sample is a matched sample. The results point to a further reduction in the impact indicators, suggesting that controlling for observed differences in the pretreatment trends of the impact variables also contributes to a reduction in the bias. Indeed, we found a positive impact on employment (4.6%), labor productivity (4.7%) and total factor productivity (5.5%), while we did not find any impacts on skills. Two qualifications are important to these results: (a) the fact that the results for total factor productivity are higher than in the OLS case is consistent with the previous finding that FONTEC firms suffered from severe productivity shocks that induced them to participate; (b) the lack of significance of the skills variables may suggest an uneven share of the rents resulting from the innovation process between the firm and the workers. Unfortunately, better quality data on skills is needed to explore this in more detail.

TABLE 7
Impact results ENIA 1998-2006

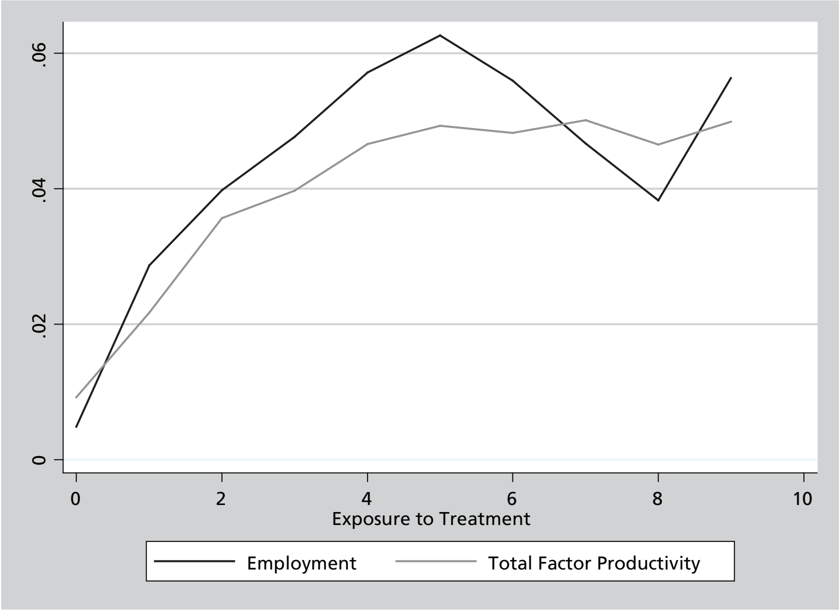
	Employment	Skills	Labor Productivity	TFP
OLS				
FONTEC	0.6439(1)	0.3048(1)	0.3536(1)	0.0370(2)
	(0.0330)	(0.0166)	(0.0248)	(0.0140)
N	57697	57697	57697	57697
F	43.4900	246.3383	87.2396	15.2439
P	0.0000	0.0000	0.0000	0.0000
Fixed effects				
FONTEC	0.0941(1)	-0.0161	0.0731(2)	0.0936(1)
	(0.0165)	(0.0169)	(0.0273)	(0.0263)
N	57697	57697	57697	57697
F	91.5211	419.2287	12.6998	14.1213
P	0.0000	0.0000	0.0000	0.0000
Fixed effect-propensity score matching				
FONTEC	0.0467(2)	-0.0002	0.0477(3)	0.0552(2)
	(0.0175)	(0.0178)	(0.0290)	(0.0279)
N	8805	8805	8805	8805
F	12.7532	56.4701	5.6025	6.0655
P	0.0000	0.0000	0.0000	0.0000

Source: Authors' elaboration using ENIA 1998-2008.
Clustered standard errors in parentheses. Year effects included.
(1) $p < 0.01$.
(2) $p < 0.05$.
(3) $p < 0.10$

A useful feature of the panel structure of our data is that it allows beneficiaries to be tracked over time, showing how impacts change over a different "exposure time" (number of years after treatment). We ran the previous results for different sub-samples of treated firms where each sub-sample was defined on the basis of the number of years that had passed for each firm since it received its first FONTEC grant. The results for employment and total factor productivity are summarized in

Graph 3, where it is possible to see that impacts are strongly cumulative and that some time needs to pass after treatment in order to detect any impact at all. Indeed, impacts, if any, are very small during the first two years of treatment. However, the results start showing some consistency 4 or 5 years after treatment. We think this finding is very important. Many previous evaluations of Technology Development Funds in Chile and other LAC countries tended to be carried out over time periods that are too short to detect any impact on performance. Although short time periods are fine in order to identify impacts on innovation investments, more time needs to be allowed in order to detect consistent impacts on performance variables such as employment or productivity. Also, for robust cost-benefit analysis of a given policy, the tracking of impacts over time is a key input in order to estimate the discounted value of a given intervention.

GRAPH 3
Tracking the evolution of impacts over time. ENIA 1997-2006



Source: Authors' elaboration using ENIA 1997-2006.

5. Conclusions

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

Applying these techniques, we found evidence of positive impacts of the subsidies granted by FONTEC on innovation investments, on R&D, and on R&D carried out with other actors of the innovation system. However, we did not find evidence supporting either crowding-in or crowding-out effects, which means that the average firm-level investment in innovation increased just by the full amount of the average subsidy. Interviews with firms indicated that the lack of leveraging effect was more likely due to an adjustment in the portfolio of R&D projects and to underestimation of the human capital needed to perform the projects, rather than to resource diversion towards non-R&D related investments.

We also found a positive impact of the program on employment growth, labor and total factor productivity growth. We did not find any significance evidence of impact on skills. However, as also suggested by Benavente et al. (2005), R&D activities take some time to have a productive impact. In fact, according to our estimates at least four years need to pass after treatment in order for the impact of Technology Development Fund on firms' performances to be fully realized.

This evaluation clearly shows the need for more frequent public policy impact evaluations aimed at supporting investment in R&D by private firms, in particular when the policies concerned involve grant aid (i.e. non-reimbursable funding). This does not imply any additional burden for program operations. This paper demonstrates 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. Close coordination among the evaluation, innovation agencies and national offices of statistics is needed for this.

The evaluation summarized in this paper clearly opens up new questions on how to design impact evaluations that not only provide information on whether a given policy is effective but also may provide additional information that is crucial if precise conclusions are to be derived that contribute to the design of successful policies. We close this section by briefly sketching some aspects that need to be considered for future work

In line with most of the impact evaluation tradition, this paper analyzes the binary case of participation against non-participation in a given innovation program; however, in practice it is generally the case that units may differ not only in binary treatment status (participant versus non-participant) but also in treatment intensity. For instance, firms may receive different amounts of public subsidy, including more than one grant for the same program, and different research teams may be granted different levels of funding. This fact raises important issues to consider when designing an evaluation: the key question is not only whether participants perform better than non-participants, but also how different intensities of treatment may affect performance and whether it is possible to find an "optimal level" for intervention (e.g. the amount of financing that maximizes the effect on firm performance).[18] In terms of evaluation design, this entails building registries of beneficiaries with information not only on when a given company received a grant, but also on the amount of the grant and the actual disbursement of it.

Also, in contexts where "multiple treatments" are available, the evaluator may be interested not only in the individual effects of each treatment, but also in potential interactions among them. In fact, it is not obvious that the effect of multiple programs will be additive; instead, it may be the case that the combination of different interventions has multiplicative effects or, on the contrary, one treatment cancels out the effect of the other. Investigation of the joint effect of different types of interventions may therefore be crucial for the design of effective policies.

In most relevant contexts, it may be hard to accept that a given intervention will have a constant effect, i.e. the same impact on all units under study. Two main types of impact heterogeneity may arise. One occurs when interventions have differential effects for different groups; for instance, matching grants may have a higher impact for young innovators. The second type is related to the distribution of the effects; for instance, two programs may have the same average impact, but the effects of one may be concentrated in the lower part of the performance distribution (FRÖLICH; MELLY, 2010).

In these contexts, restricting the analysis to the average impact for the treated population may give an incomplete or at least imprecise assessment of the effect of a program. It is therefore of great interest to account for the possibility of impact heterogeneity in order to give a precise assessment of the effects of an intervention.

18 Exceptions to this are Binelli and Maffioli (2008).

Finally, consistent with our previous discussion, a given innovation support program can have side effects. For instance, a subsidy that favors a certain kind of enterprise may put other firms at a competitive disadvantage. During the time they receive public support, the beneficiaries can outpace the followers in a "winner takes all" game. Conversely, there can also be positive spillovers from supported projects to others via the transmission of knowledge between firms or rent spillovers. In the former case, firms that do the same kind of innovative project are likely to benefit from each others' research. In the latter case, a firm may indirectly benefit from an R&D+I program if it produces a product that makes use of new inputs produced by upstream supported innovative firms. The likely presence of externalities should also be taken into account when devising random experiments or when creating appropriate control groups.

Besides the externality effects on the performance of other firms, an innovation support program can also have general equilibrium effects that should enter the welfare calculation. For example, a matching grant program can raise the wages of scientists and engineers if their supply is inelastic and thus indirectly increase the cost of doing research in an economy and possibly slow down the innovation activity in unsupported activities. An intellectual property right, like a patent, leads to a temporary monopoly position with negative effects on competition and consumer surplus. All these factors must be considered when designing the evaluation to assure proper estimattion of the different types of impact of a public program.

Bibliographical references

AGOSIN, M. *Políticas de innovación en Chile*, IDB Manuscript, Washington DC, 2009.

ALVAREZ R.; CRESPI, G. Multinational firms and productivity catching-up: the case of chilean manufacturing. *International Journal of Technological Learning, Innovation and Development*, v. 1, n. 2, p. 136-152, January 2007.

ALVAREZ, R.; BENAVENTE, J. M.; CAMPUSANO, R.; CUEVAS, C. *Employment generation, firm size, and innovation in Chile*. IDB Publications 54258, Inter-American Development Bank, 2011.

ARROW, K. Economics welfare and the allocation of resources for invention. In: NELSON, R. (Ed.). *The rate and direction of inventive activity*. Princeton University Press, 1962, p. 164-181.

BECKER, S.; ICHINO, A. Estimation of average treatment effects based on propensity scores. *The Stata Journal*, v. 2, n. 4, p. 358-377, 2002.

BENAVENTE, J. M. *Determinants of industrial research and innovation*: the case of Chile. Unpublished DPhil Thesis, University of Oxford, 2002.

BENAVENTE, J. M.; DE GREGORIO, J.; NUNEZ, M. Rates of return and the industrial R&D in Chile. Santiago, Chile: University of Chile and Central Bank of Chile, paper presented at the World Bank conference in Barcelona on on R&D and Innovation in the Development Process, 2005.

BENAVENTE, J. M.;CRESPI, G. Biases and weaknesses of Chile's NSI. In: AGOSIN, M.; SAAVEDRA, N. (Eds.). *national innovation systems, what Can Latin America learn from Japan?* Santiago: Dolmen Ediciones, 1998.

BENAVENTE, J. M.; CRESPI, G. MAFFIOLI, A. *Public support for firm innovation*: the experience of chilean FONTEC. 2007 (OVE working paper, 05/07).

BENAVENTE, J. M; PRICE, J. J. Apoyo publico a la innovacion empresarial: de FONTEC and nuestros dias. In: MUNOZ, O. (Ed.). *Desarrollo productivo en Chile.* La experiencia de CORFO entre 1990 y 2009. CORFO-FLACSO, 2009.

BLUNDELL, R.; COSTA DIAS, M. *Alternative approaches to evaluation in empirical microeconomics*. Centre for Microdata Methods and Practice, Institute for Fiscal Studies, 2002 (CeMMAP working papers, CWP10/02).

CIMOLI, M.;DOSI, G. Technological paradigms, patterns of learning and development. An introductory roadmap. *Journal of Evolutionary Economics*, v. 5, n. 3, p. 243-268, 1995.

CREPON, B.;DUGUET, E.; MAIRESSE, J. *Research, innovation, and productivity:* an econometric analysis at the firm level. National Bureau of Economic Research, Inc, 1998 (NBER working papers, 6696).

DAVID, P.; HALL, B.; TOOLE, A. Is public R&D a complement or substitute for private R&D? A Review of the Econometric Evidence. *Research Policy*, n. 29, p. 497-529, 2000.

DINI, M.; STUMPO, G. *Anális de la politica de fomento a las pequeñas y medianas empresas en Chile*. CEPAL/ECLAC, 2002 (Serie Desarrollo Productivo, 136).

DOSI, C.; NELSON, R. (Eds.). An introduction to evolutionary theories in economics. *Journal of Evolutionary Economics*, v. 4, n. 3, p. 153-172, 1994.

DOSI, C.; FREEMAN, C.; NELSON, R.; SILVERBERG, G.; SOETE, L. (Eds.). *Technical change and economic theory*. London: Pinter, 1998.

DUGUET, E. *Are subsidies a substitute or a complement to privately funded R&D?* Evidence from France using propensity score methods for non-experimental data. Université de Paris I, 2004 (Working Paper, 75).

GERENS, *Fontec-Innovación Tecnologica*: una estimación de sus beneficios socials. Santiago, 1996. Mimeo.

GRILICHES Z. Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, n. 28, p. 1661-1707, 1990.

Hall, B. H. The financing of research and development. *Oxford Review of Economic Policy*, n. 18, p. 35-51, 2002.

IDB. *CH0022: Science and Technology Program*. Washington, DC: Inter-American Development Bank, 1991..

KLETTE, T.; MØEN, J. From growth theory to technology policy – coordination problems in theory and practice. *Nordic Journal of Political Economy*, n. 25, p. 53-74, 1999.

ILADES *Un análisis económico de los proyectos de innovación tecnológica apoyados financieramente por FONTEC.* Santiago, 1999. Mimeo.

LERNER, J. The government as venture capitalist: the long-run impact of the SBIR program. *Journal of Business*, v. 72, n. 3, p. 285-318, 1999.

LEVIN, R.; KLEVORICK, A.; NELSON, R.; WINTER, S. Appropriating returns from industrial research and development. *Brookings Papers on Economic Activity*, n. 3, p. 783-831, 1987.

Lundvall B. (1988), "Innovation as an Interactive Process: from User-Producer Interaction to the National System of Innovation", in G. Dosi, C. Freeman, R. Nelson, G. Silverberg, L, Soete (eds.), *Technical Change and Economic Theory*, London: Pinter.

LUNDVALL, B. (Ed.). *National System of Innovation*: towards a theory of innovation and interactive learning. London: Pinter, 1992.

MANSFIELD, E.; SCHWARTZ, M.; WAGNER, S. Imitation costs and patents: an empirical study. *Economic Journal*, n. 91, p. 907-918, 1981.

MARTIN, S. The evaluation of strategic research partnerships. *Technology Analysis & Strategic Management*, v. 15, n. 2, p. 159-176, 2000.

_________.Competition policy, collusion, and tacit collusion. *International Journal of Industrial Organization*, Elsevier, v. 24, n. 6, p. 1299-1332, 2006.

MARTIN, S.; SCOTT, J. The nature of innovation market failure and the design of public support for private innovation. *Research Policy*, n. 12, 437-447, 2000.

METCALFE, J. S. Evolutionary economics and technology policy. *The Economic Journal*, n. 104, p. 931-944, 1994.

MORGAN, K. Learning by interacting: inter-firm networks and enterprise support. In: OECD (Ed.). *Networks of enterprises and local development*. Paris: OECD Publications,1996.

NELSON, R. The simple economics of basic scientific research. *Journal of Political Economy*, v. 67, n. 3, p. 297-306, 1959.

_________. Why do firms innovate, and how does it matter. *Strategic Management Journal*, n. 12, p. 61-74, 1991.

NELSON, R.; WINTER, S. *An evolutionary theory of economical change*. Cambridge, MA and London: Harvard University Press, 1982.

OECD. *Oslo manual*: guidelines for collecting and interpreting innovation data. 3rd Edition, 2005.

POWELL, W.; KOPUT, K.; SMITH-DOERR, L. Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly*, n. 41, p. 116-145, 1996.

ROSENBAUM, P.; RUBIN, D. The central role of the propensity score in observational studies for causal effects. *Biometrika*, v. 70, n. 1, p. 41-55, 1983.

TEUBAL M. *Marco de políticas para el financiamiento de la innovación en economías en vías de industrialización*. SDS WP, 1998.

TOIVANEN, O. *Innovation policy, entrepreneurship and development*: a finnish view. UNU-MERIT, 2009 (Working paper series #2009-050).

UNIVERSITY OF CHILE. *Evaluación de los resultados económicos de los proyectos de innovación tecnológica financiados por el FONTEC*. Santiago, 2004. Mimeo..

VIVARELLI, M. *Innovation, employment and skills in advanced and developing countries:* a survey of the literature. IDB Publications 61058, Inter-American Development Bank, 2011.

Appendix

Propensity score model

Participation Model ENIAT 05	Coefficient	Participation Model ENIA	Coefficient
Age	0.0014	Located Santiago	0.2207(1)
	0.0054		0.0418
Foreign-Owned	-0.4178(2)	Exported (t-1)	0.4919(1)
	0.2417		0.0526
Located Santiago	0.1556	Employment (t-1)	0.4787(3)
	0.1194		0.1547
Employment 2003 (LN)	0.4534(2)	Employment (t-2)	-0.3998(2)
	0.2773		0.1555
Employment 2003 (LN)^2	-0.0419	Skills (t-1)	-0.0884
	0.0292		0.0844
Labor Productivity 2003 (LN)	0.0534	Skills (t-2)	0.1136
	0.0460		0.0812
Exporter 2003	0.3215(2)	Labor Productivity (t-1)	0.9857(3)
	0.1472		0.356
Natural Resource Sector	-0.4028(2)	Labor Productivity (t-2)	-1.0276(3)
	0.1891		0.3561
Labor-Intensive Sector	-0.4207(2)	TFP (t-1)	-0.9474(3)
	0.1738		0.3595
Scale-Intensive Sector	-0.1882	TFP (t-2)	0.9353(3)
	0.1712		0.3557
Innovation Exp to Sales 2003	2.7828(1)	Natural Resource Sector	-0.2542(1)
	-0.8811		0.0514
R&D to Sales 2003	-1.6630	Labor Intensive Sector	-0.5808(1)
	-2.1435		0.0708
R&D Share of Innovation 2003	0.5195(3)	Scale Intensive Sector	-0.1084
	-0.2237		0.0556
Contracted R&D 2003	-0.1491		
	-0.3484		
_cons	-3.0306(1)	_cons	-2.5735(1)
	-0.7546		0.2749
N	1118	*N*	37880
r2_p	0.0854	r2_p	0.0791
chi2	52.3016	chi2	434.6097
P	0.0000	P	0.0000

Clustered standard errors in parentheses. Year effects included for the ENIA model.
(1) $p < 0.01$; (2) $p < 0.10$; (3) $p < 0.05$.

CORRESPONDENCE ADDRESS:

Jose Miguel Benavente – jmbenavente@uai.cl
Business School, Universidad Adolfo Ibáñez, Diagonal Las Torres 2700 of 305, Peñalolen, Santiago, Chile

Gustavo Crespi – gcrespi@iadb.org
Inter-American Development Bank, 1300 New York Av, Washington DC, 20577, Stop E0603

Alessandro Maffioli – alessandronm@iadb.org
Inter-American Development Bank, 1300 New York Av, Washington DC, 20577, Stop E0805