Inter-American
Development Bank

Social Sector
Science and Technology
Division

TECHNICAL NOTES

No. IDB-TN-264

Public Support to Innovation: the Colombian COLCIENCIAS' Experience

Gustavo Crespi
Alessandro Maffioli
Marcela Melendez

April 2011

Public Support to Innovation: the Colombian COLCIENCIAS' Experience

Gustavo Crespi
Alessandro Maffioli
Marcela Melendez

Inter-American Development Bank
2011

Public Support to Innovation: the Colombian COLCIENCIAS' Experience

Gustavo Crespi[1], *Alessandro Maffioli*[2], *Marcela Melendez*[3]

Abstract

This paper aims at evaluating the impacts of innovation promotion programs administrated by the Colombian Innovation Agency (COLCIENCIAS). Although the agency implements multiple programs, the focus of these research are on those programs that provide financial incentives for R&D (matching grants and contingent loans) and at the same time encourage the formation of linkages between firms, universities and other public research organizations. Different from previous evaluations, a nice feature of the current research is the possibility to use a very rich dataset in order follow-up the economic performance of the beneficiaries over a long period of time. The results show that after controlling for both observable and unobservable difference with the control group, COLCIENCIAS programs have been very effective in increasing firm labor productivity and that the main channel behind this result is product diversification (product innovation).

JEL CODES: O32, O38, O31, H43

Keywords: COLCIENCIAS, Colombia, Research and Development, Matching Grants, Policy Evaluation

[1] Inter-American Development Bank, Science and Technology Division, gcrespi@iadb.org
[2]Inter-American Development Bank, Office of Strategic Planning and Development Effectiveness, alessandrom@iadb.org
[3] Marcela Meléndez, ECON ESTUDIO, Bogotá, Colombia, email: marcela.melendez@econestudio.com

1. Introduction

The promotion of investments in R&D and innovation has overtime become a pillar of public policies aimed at fostering productivity not only in developed Countries, but also in many emerging economies. In Latin America, this effort has addressed a persistent and increasing technological gap with developed economies, and, in some cases, with other fast-growing emerging economies. In this context, the persistently low participation of the Latin American private sector in R&D investment has always been of particular concern. To respond to these challenges, Latin American Governments have over time introduced various policy instruments aimed at fostering R&D and innovation in the private sector, including horizontal matching grants, thematic funding, guaranteed loans, targeted credit lines, and public procurement programs.[4]

As the adoption of these policy instruments has quickly proliferated, the question on their effectiveness also gained importance. An increasing number of studies have recently dealt with the assessment of the effectiveness of the different policy tools aimed at fostering firm level innovation. Most of these studies focus on the so-called "crowding-out" problem, whether public funding simply substitutes private resources without inducing any additional investment. Crowding-out potentially originates from information asymmetries between the public administrator and the potential beneficiary of the grant. In some specific cases, these information asymmetries could lead to a situation where the potentially positive effect of the public funding is undone by an internal transfer of private funds to other investments with no real increase in R&D spending.[5]

Although the results are not totally conclusive, the majority of studies tend to reject the full crowding-out hypothesis. David, Hall and Toole (2000) and Klette, Møen and Griliches (2000) provide a comprehensive review of the main empirical studies measuring the impact of public funding on firms' investment in innovation during the 1990s in developed economies. According to David et al., two-thirds of the studies report that public R&D funding did not substitute private R&D investments. In the last decade, this kind of analysis has multiplied, thanks to the increasing availability of data, providing some additional insights into the effectiveness of public support of private innovation. Aschhoff (2009) provides an updated review of the most significant results of these studies. Most of them confirm the

[4] Some countries are also experimenting with fiscal incentives with some degree of intensity (in particular Argentina, Brazil, Chile, Colombia and Mexico). However, the results here are far more limited as the programs are more recent (see Argentina or Brazil) or have restricted coverage by design (Chile where the incentives are restricted to firms collaborating with public research organization). For a review of the impacts of fiscal incentives in developed countries see Hall and Van Reenen (2000). For an evaluation of the Colombian case see Mercer-Blackman (2008).

[5] For a complete discussion on this topic see Hall and Maffioli (2008).

absence of full crowding-out effects, and some also show evidence of multiplier effects on private investments.[6] Some studies focus on the potential heterogeneous effect of public financing, suggesting that subsidies are more effective for smaller firms, which is consistent with the financial constraint argument.[7] Other studies address the relationship between the amount of subsidy received and size of impact, i.e. the so-called "dosage effect", with some studies finding that evidence of higher effects of larger subsidies,[8] while other studies obtaining evidence of decreasing returns.[9]

Fewer studies analyze the effect of public support on innovative output (patents, numbers of new products and sales of new products) and firms' performances. Although some positive effects are detected, the results are in general inconclusive. The main difficulty in this case is that a longer time horizon is required to detect these effects. In fact, while crowding-out or multiplier effects can be detected almost in conjunction with the receipt of public financing, other effects are detectable only after the innovation and learning process has come to an end.[10] This implies that rigorous impact evaluations of these effects may require panel data for a minimum period of five years after the receipt of public financing.

Until lately, most evaluations have focused on developed countries, mainly because of the lack of data in developing countries. For this reason, the literature on Latin American countries is relatively recent, although growing. Hall and Maffioli (2008) synthesized the results of a series of evaluations of Technology Development Funds (TDFs) in Argentina, Brazil, Chile and Panama,[11]carried out by the IDB between 2005 and 2007. The studies reviewed consider four levels of potential impact: (i) R&D input additionality, (ii) behavioural additionality, (iii) increases in innovative output, and (iv) improvements in performance. The evidence shows that TDFs do not crowd out private investment and have a positive effect on the intensity of R&D. In addition, TDFs induce in beneficiary firms a more proactive attitude towards innovation. However, the studies do not find consistent effects on patents or new product sales and the evidence on firm performance is also mixed, with positive results in terms of growth, but little corresponding impact on measures of productivity. Because this can be due to the short time period in which the evaluations were conducted, the Hall and Maffioli conclude that additional impact evaluations based on longer panel data are needed to shed some light on long-run effects.

[6] These studies include Fier (2002), Licht and Stadler (2003), Czarnitzki and Hussinger (2004) and Hussinger (2008).
[7] These studies include Lach (2002), González, Jaumandreu and Pazó (2005) and González and Pazó (2008).
[8] Aschhoff (2009).
[9] Lerner (1999).
[10] Even regarding the dynamics of investments, evidence for Israel shows that companies tend to use spend first the grant component of a supported R&D project, then when they are certain of the effects tend to increase, sometimes substantially, the private funding component. Overall there is crowding-in but the timing of the evaluation also matters for the study of this effect (see Lach, 1999).
[11] The survey includes the following studies: Chudnovsky et al. (2006) Binelli and Maffioli (2007), Benavente et al. (2007), De Negri J., Borges Lemos and De Negri F. (2006a) and De Negri et al. (2006b).

More recently, López Acevedo and Tan (2010) provided an evaluation of SME credit programs in Mexico (Nafinsa, Bancomext, CONACyT, STPS and other programs from the Ministry of Economy), Chile (SENCE, CORFO, PROCHILE, FONTEC), Colombia (FOMIPYME) and Peru (BONOPYME, PROMPYME, CITE). The authors find positive gains in sales, labor productivity and employment in Chile, and higher value added, sales, export and employment in Mexico. In Colombia, the results suggest positive effects on exports, investment in R&D and TFP. Finally, in Peru the findings show significant positive effects in sales and profits. Confirming the findings of Hall and Maffioli, López Acevedo and Tan note that some of the estimated impacts do not materialize until after several years. Thus, they claim that the lack of impact of previous studies may be due to the short time dimension of the available databases, and remark the importance not only of controlling for potential selection biases but also to account for time lags to correctly estimate the effects of credit programs.

This paper contributes to this growing literature by analyzing the long run effects of a Colombian program that promotes firm-level innovation trough a matching-grant funding scheme. To shed some light on the long-run dynamic effects TDFs, we analyze the effects of matching-grant and credit programs managed by the Colombian innovation agency –COLCIENCIAS- using panel data that allow us to detect the long-run effects of the program. The evaluation relies on a unique data set generated by merging the administrative records from COLCIENCIAS with the Annual Manufacturing Survey (EAM, from its Spanish name) and the Colombian National Innovation Survey (EDIT, from its Spanish name), both collected and managed by the Colombian Statistical Office DANE. In this way, we estimate the effect of public funding on firm-level indictors over a 13-year period.[12]

Our findings show that COLCIENCIAS funding had a significant impact on firm their performance. They also provide evidence that these effects remain and, in some cases, increase over time. Of particular interest are the effects on productivity: over the period 1995-2007 COLCIENCIAS funding had an average impact on introduction of new products and labor productivity of around 12% and 15% percent respectively, with these effects becoming more significant between three to five years after the firms started being treated. These findings imply not only that beneficiary firms become more efficient, but that they grow more and gain a greater market share than the control group. The consequence is that economic resources are being reallocated towards more productive firms, hence impacting also productivity "in the aggregate".

Our findings are based on a core specification aimed at removing biases due to firm-level fixed effects (observable and unobservable). In addition, to test the robustness of our results, we combined the

[12] Given the confidentiality of the data, the estimations were conducted following DANE's microdata-access policy, which implies working in situ under the supervision of DANE's staff and with blinded access to sensible information.

fixed-effect estimations with common support samples (based on the firm's characteristics before participation) and we checked for endogenity through the estimation of anticipatory effects. The main limitation of our approach is that data linking can only be done on already existing data registers. So, in this case, the use of the EAM somehow restricts the analysis to manufacturing firms and firms with more than 10 employees.

2. The Antecedents and Institutional Settings of the COLCIENCIAS Program

Colombia's innovation system has followed an evolutive path for a very long time. Indeed, the first universities were established well in 1803 with the creation of the Universidad Central de la República, the precursor of the current National University. More recently, sectoral research and technology transfer centers were created for the main export sectors of the country (such as coffee and sugar cane during the 1930s). However, from an institutional point of view, a first milestone was the passing of the Law 34 in 1973 designating the National Science and Technology Council (COLCIENCIAS) as the overall coordinators of the activities in the sector. At the beginning the focus of the policy intervention was on the creation of capabilities on the supply side, that is, through the funding of post-graduate scholarships, infrastructure and scientific research. Despite these advances towards the end of the 80s, the overall system was still underdeveloped with a volume of scientific and technical research still too small relative to the regional levels, lack of enough advanced human resources and with very little share of the productive sector in the national R&D budget.

Confronting this scenario, the government passed in 1988 the new National Science and Technology Plan stressing the need to improve the institutional coordination within the system and also to improve the linkages with the private sector. A National Science and Technology Council was put in charge of the sector's policy design and of coordinating the activities of the NSTS, and COLCIENCIAS became the technical secretariat of that Council. Additionally, policy implementation was scaled-up through multilateral funding in particular encouraging linkages between research centers and users and furthering innovation and technological development within business, among other things. During the 90s, despite the evident increase in the amount of resources channeled to R&D and training, these institutional arrangements were not enough as to guarantee an adequate stream of national funding to the sector. Indeed, during that period COLCIENCIA's budgets fluctuated pari-passu with the availability of multilateral funding. Additionally, the linkages between supply and demand continue to be weak while

the lack of coordination within the government and overlaps remained important. Within these limitations is important to emphasize the institutionalization of new actors such the network of Centers of Technological Development (CTDs), created between 1995 and 2002, which comprise National Centers for Sector Development, Incubators of Enterprises of Technological Base, Regional Centers of Productivity, and Technological Parks.

Since 2004, with the improvements of the overall macroeconomic conditions of the country, COLCIENCIAS' budget started to grow again reaching the levels of mid 1995 but this time without multilateral funding. The increase in the national priorities towards science and technology became even more evident with passing of the Law 1286 of 2009, through which COLCIENCIAS is elevated to the category of Administrative Department (a Ministry in practical terms) and granted budgetary independence. Currently COLCIENCIAS budget is split among three main policy initiatives: (i) strengthening of STI capacities, mainly through the co-financing of basic and apply research carried-out by universities and other public research organizations (41% of the total investment budget of COLCIENCIAS), (ii) S&T training, through the implementation of different scholarship programs for graduate and post-graduate studies (28% of the total investment budget) and (iii) business innovation through the delivery of credit lines and matching grants (18% of the total investment budget)[13]. All these resources are allocated on competitive bases, according to the quality of technical proposal submitted by the beneficiaries and assessed by a system of peer-reviewers. The subjects of this evaluation are the COLCIENCIAS' programs that support business innovation. One of this is the Program "Cofinanciación (Co-Funding)", that provides grants up to 50% of the project total amount for large enterprises and up to 70% for SMEs and microenterprises and after the fiscal incentives, is the main mechanism to support business innovation and university-industry collaboration in Colombia. Indeed, under this program firms apply for the grants through the submission of a project proposal. The proposal must indicate who the technology service provider would be (either a university or a CTD). If approved, COLCIENCIAS funds a proportion of the total cost of the projects (the remaining part being funded by the firm) and, although the grant contract is signed by the firm, the technology provider and COLCIENCIAS, public resources are transferred directly to the technology provider. According to COLCIENCIAS this minimizes the chances of impropriate use of the resources (or crowding-out) by the private sector. The second program is a credit line (called "Reembolso Obligado") that provides partial funding for innovation projects submitted by individual firms.

[13] Colciencias also manages an R&D Tax Credits programs, however these resources are not integral part of Colciencias budget and so they are not included in the previous figures. The fiscal incentives are in place since 1992 and comprise a 25% deductible over expenditures in science and technology and VAT exemptions for assets purchases.

3. The Rationale of the COLCIENCIAS' Innovation Programs

The economic literature has extensively documented many market failures that lead to private sector under-investment in innovation.[14] These market failures arise from four main sets of reasons: (i) incomplete appropriability of the innovation rents; (ii) asymmetric information and moral hazard that limit access to external funding – issue that is exacerbated by the intangible nature of the assets accumulated through R&D investments, (iii) the technological and commercial uncertainties associated with an innovation endeavor and (iv) network externalities and coordination failures, mainly related to the diffusion of general purpose technologies (see Aghion, David and Foray, 2009).

The prime, and most accepted, justification for S&T policies comes from the need to correct market failures caused by the "public good" nature of knowledge.[15] In this view, non-appropriable benefits associated with the creation of knowledge make private investment fall short of social optimal levels. To respond to this problem, the public sector usually plays a major role in financing investments in R&D. Different intervention models, not necessarily mutually exclusive, are adopted, ranging from the establishment of public research organizations to the provision of research grants through competitive processes and Intellectual Property Rights (IPRs).

Asymmetry of information in the financial markets is another key justification for public funding of research and innovation activities. The asymmetry of information between the lender and the borrower on the technical contents of innovation projects may limit the availability of private funding. A number of policy instruments address the financial constraints in innovation, including public subsidies, tax incentives, targeted credit lines co-managed by financial intermediaries and public agencies specializing in the screening of innovation projects, and even public venture capital organizations.

The lack of technical information, the sunk costs nature of innovation investments and the intrinsically high uncertainty of research and innovation outcomes are additional reasons for public intervention in S&T. Projects with a significant component of basic research are unlikely to produce results with commercial application in the short run. Although this may discourage private investments, the projects could still have a high social return because of the skills and knowledge produced during their development, apart from their final achievements.[16] To mitigate these problems, governments use grants

[14] See, for example, Levin et al. (1987), Mansfield et al. (1981) and Martin and Scott (2001).

[15] Since the seminal works by Nelson (1959) and Arrow (1962), scientific and technological knowledge has been defined as a durable public good, i.e. nonexcludable and nonrival. Furthermore, the nonrival character of new knowledge intensifies the need for creating incentives that can compensate for the nonappropriable benefits.

[16] The uncertainty could be both technical and commercial in nature. In the former case, it is not clear ex ante if the research projects will be able to achieve the technical solution to certain problems. In the latter case, the uncertainty is related to difficult assessment of the final users' willingness to pay for a product or services that cannot be tested

and subsidies to reduce the financial risk of innovation to the firm via cost-sharing, promote the use of public procurement to reduce uncertainty and to signal to private investors the profitability of the project and encourage university-industry collaboration projects that allow firms to diversify risk, to get access to specialized technical information and to share the use of complex and expensive equipment.

Several coordination failures can also require public interventions. The low appropriability of the investment in research activities causes externalities that may benefit firms or agents operating in the same sector, including potential competitors (free riding). In this situation, the coordination of investment decisions may lead to a better equilibrium, either because more investment projects become profitable, or because costs are not duplicated in separate efforts that lead to identical results. The creation of research groups or consortia including firms, users and technology providers such as universities and CDTs, for instance, allows such groups to internalize some externalities of the research results, reducing the potential duplication of investment in developing knowledge with low direct commercial application. In this case, public intervention is often required to reduce the transaction costs that may hamper the formation of the consortia and to regulate their activities in order to achieve the desired balance between cooperation and competition.[17] Closely related to the idea of coordination failures, is the evolutionary economics[18] idea that innovation is the result of collective learning, which is clearly dependent on firms' building enough absorptive capacities. According to this view public intervention is not only justified in due the conventional cases of market failures described above, but also due to non-market or coordination failures, such as the lack of enough linkages among different innovation system actors and their lack of absorptive capacities. This literature has devoted an increasing level of attention to the potential social benefits of networking and interactive learning. Firms could benefit from 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.[19]

The COLCIENCIAS' innovation programs present multiple objectives nested within the different interventions. On the one hand firms receive a subsidy (with rates declining with firm's size) in principle targeting the lack of appropriability and financing that harm innovation, but also generating incentives in

---

yet. Finally, the uncertainty and indivisibility of knowledge investments cause an even greater suboptimality in the allocation of resources.

[17] The regulation may allow and encourage firms to coordinate their R&D investment during the first stage of a project (e.g., the basic research stage) and then force them to engage in Cournot or Bertrand-type competition in the second stage (e.g., prototype development). On this topic, see among others Martin and Scott (2000).

[18] See Nelson and Winter (1982), Dosi (1988), Dosi and Nelson (1994), Metcalfe (1994), Cimoli and Dosi (1995) and Teubal (1998).

[19] According to the "network of learning" (Powell, Koput, Smith-Doerr 1996) and to the "interactive learning" approaches (Lundvall 1988 and 1992, Morgan 1996), networks facilitate organizational learning and act as a locus of innovation. Thus, "organizational learning is both a function of access to new knowledge and the capabilities of utilizing and building on such knowledge" (Powell, Koput and Smith-Doerr 1996: 118).

order to induce firms to collaboration with other innovation system's actors, such as universities and CDTs, alleviating the uncertainty and coordination failures that harm innovation.

4. The Evaluation of the COLCIENCIAS Line of Financing: Research Questions[20]

In our empirical analysis, we look at the impact of COLCENCIAS funding on firms' performance. In fact, looking at changes in innovation efforts is a necessary but not sufficient condition to infer that the program could have a positive impact on social welfare. For this reason, we also want to determine whether the potential increase investment induced by the programs leads to a better performance at the firm level, or, in other words, to productivity gains.

For this purpose, we use labor productivity as our key indicator of performance. We define labor productivity as value added (that is sales minus intermediate inputs) divided by total employment. We recognize that a better indicator might have been total factor productivity (TFP), however TFP requires some assumptions about the production function model and it also requires high-quality data on capital stocks and fixed capital investment. Because this would imply a higher level of complexity due to the need to work data which is contaminated by measurement errors, we prefer working instead with the cleaner measure of productivity, i.e. labor productivity. To complete our analysis, we also explore the mechanisms through which labor productivity could have increased as a result of the program. There are in principle three channels to be considered: (i) product innovation and diversification, (ii) better production efficiency through labor saving and (iii) an increase in capital intensity. These three channels will be also assessed in this paper.[21]

Description of the Data

We have three firm-level data sources that we use in estimation. The first one is a database provided by COLCIENCIAS that contains the record of firm utilization of COLCIENCIAS instruments for the

[20] In a parallel research we are also looking at the impacts of COLCIENCIAS funding on R&D and innovation investments. These results will be integrated to this piece of work when become available.

[21] We recognize that between innovation efforts and productivity results there might be a set of innovation outcomes (such as new products, new process, patents, etc) Although information regarding to these innovation outcomes is already included in the EDIT, the same one is not included in the EAM, so these results cannot be assessed over time frames.

promotion of innovation, namely the monetary amounts received from COLCIENCIAS and the modality under which were delivered, credit or co-financing, from 1995 to 2007.

The second one is the Annual Manufacturing Survey ("Encuesta Anual Manufacturera," henceforth EAM) collected by the Colombian Statistical Office DANE.[22] The survey represents a complete Census of the manufacturing sector, which accounts for approximately 15% of Colombian GDP, and is available from 1977 to 2007. It collects detailed information on firms' production processes and activity (outputs, investments, inputs and expenses), and on firm performance. For the purpose of this research we have constructed a panel dataset for the period 1995-2007 that allows us to follow plant-level performance over time. We drop all observations of plants appearing only one year in the data or belonging to firms that own multiple plants, which cannot be properly matched to the COLCIENCIAS one.

The third database is the 2005 Technological Innovation Survey (EDIT, for its acronym in Spanish), also collected by DANE. It contains detailed information about firms' innovation activities for years 2004 and 2003, including expenditures in R&D and total expenditures, as well as information about sources of funding (COLCIENCIAS, among them). EDIT is collected every three years (the next wave for 2008 is still under consistency checks at DANE) and completed by the same firms that are surveyed for EAM. The three databases contain firm identifiers that make it possible to combine them for estimation purposes. Table 1 presents a characterization of the manufacturing firms participating in COLCIENCIAS programs between 1995 and 2007, according to the data provided by COLCIENCIAS.

Table 1: Manufacturing Firms Using COLCIENCIAS' Programs

Year	Number of firms	%	Output (USD thousand)	%	Employment	%	Exports (USD thousand)	%	Fixed Assets (USD thousand)	%	Average firm size by output (USD thousand)	Average firm size by employment
1995	4	0.0	71,508	0.3	513	0.1			5,907	0.32	17,877	128
1996	12	0.1	139,018	0.6	2,093	0.5			13,369	0.52	11,585	174
1997	12	0.1	147,012	0.6	1,972	0.4			15,812	0.48	12,251	164
1998	20	0.2	353,985	1.5	5,554	1.3			99,933	2.23	17,699	278
1999	20	0.3	360,203	1.7	4,966	1.3			105,707	1.98	18,010	248
2000	19	0.2	348,211	1.4	4,312	1.1	60,848	2.1	79,946	1.22	18,327	227
2001	23	0.3	493,002	1.9	5,181	1.4	96,824	2.6	135,909	1.87	21,435	225
2002	32	0.4	759,490	3.0	7,399	2.0	184,321	4.4	308,682	3.88	23,734	231
2003	45	0.6	1,327,997	4.8	10,487	2.7	224,294	4.6	683,985	8.42	29,511	233
2004	50	0.7	1,563,395	5.1	12,004	2.9	310,902	5.8	675,102	7.64	31,268	240
2005	59	0.8	1,936,478	6.0	14,112	3.3	301,131	4.9	790,580	9.37	32,822	239
2006	59	0.8	2,145,227	6.0	14,633	3.2	506,327	7.0	906,058	9.81	36,360	248
2007	57	0.8	1,852,090	4.9	14,673	3.1	387,740	5.3	732,841	8.38	32,493	257

Source: COLCIENCIAS, DANE's Annual Manufacturing Survey (EAM) and calculations by the authors. Monetary values are 2008 pesos converted to USD at that year's average exchange rate. Firm-level exports data are only available since 2000 in EAM.

[22] EAM firm-level data are protected by a statistical reserve regulation. We were able to work with them at DANE's offices, thanks to a special cooperation agreement to facilitate academic research.

Methodology

The estimations will be based on a longitudinal database. The panel structure of this database allows us to exploit between and within-firm variability to estimate the impact of COLCIENCIAS. Assuming that unobserved heterogeneity is constant over time, some types of potential selection biases can be mitigated using a fixed effects model. More precisely, we will run the following specification:

$$Y_{it} = \alpha_i + \lambda_t + \beta Colciencias_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the outcome of firm i in year t, $Colciencias_{it}$ is a treatment indicator variable. This treatment indicator is defined as a binary variable taking the value one from the first year of participation to the end of the period under study. Under this specification, β 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 outcome 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.

Under the assumption of time-constant unobserved heterogeneity, the fixed effects model gives a consistent estimator for β, the impact of COLCIENCIAS on the outcome variable.

Although the average impact over the whole period of participation is a useful indicator of the effect of the program, further relevant information can be obtained by studying the effect of the program over time. Therefore, we then modify equation (1), changing the treatment dummy for several dummies indicating the number of years since the entry to the program:

$$Y_{it} = \alpha_i + \lambda_t + \sum_{j=0}^{k} \beta_j D_{it}^{j} + \varepsilon_{it} \quad (2)$$

Thus, $D_{i,t}^{j}$ will be equal to one on the j-th year after the entry to the program. For instance, $D_{i,t}^{0}$ will be equal to one on the entry year, $D_{i,t}^{1}$ will be equal to one in the first year after the entry, and so on.
Although, under the assumption of time-constant unobserved heterogeneity, regressions (1) and (2) should result in consistent estimators of the impact of the program, 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 biases, for the second set of results we will run regressions (1) and (2) in a common support of firms to ensure that all the groups are similar in ex-ante characteristics. We will estimate the propensity score as described in the previous paragraph

but conditioning of information from two or three years before participation. After this, we eliminated from the sample those firms that in the years before enrolling in COLCIENCIAS programs were very different from the participating firms. Equations (1) and (2) are run on the common support sample to check the robustness of the results.

5. Results

Panel Data: Full Sample

Table 2 summarizes the first set of results. The first row shows that the average impact of the program over the whole period is positive for the four outcomes of interest, although insignificant for investment / capital. According to these estimations, participating in COLCIENCIAS increases employment by 13 percent[23] and labor productivity by 16 percent; the number of products is increased by 0.093. When decomposing the treatment variable by year of participation, we find that the effect on investment over capital is positive for the first three years and negative afterwards, although again the coefficients are insignificant.

The impact on employment is positive for all years. This effect seems to be stronger after the 3rd year of treatment, and becomes insignificant after the 6th year. For labor productivity, the impact appears to be positive and fairly constant since the second year of participation. In this set of results, this outcome shows a significant effect even after 8 years of participation. As to number of products, the results suggest that COLCIENCIAS has a positive and significant effect of around 10% from the second to the 5th year of participation.

It is important to mention that while our database allows us to investigate the long term effects of the program, the coefficients corresponding to later years are likely to be more imprecise than the rest, since only a small group of firms is followed over such a long period. This seems evident, for instance, for employment: the standard error of the coefficient for the first year is 0.062, while it is equal to 0.157 for the eighth year. Thus, the lack of significance of these coefficients does not necessarily imply a lack of impact, but could due to the high variance of the estimators.

[23] [exp(beta)-1]*100

Common Support Sample

In the second set of results, we restrict the sample to ensure that participating firms are compared to untreated firms that are similar in terms of ex-ante observable characteristics using the Propensity Score method to define a common support based on pre-treatment information.

When interpreting these new results, it is important to note that the estimators are expected to have higher standard errors since the sample size is significantly smaller (in fact, the number of observations is reduced to approximately one third of the original sample). Thus, it is expected that the significance of the coefficients is smaller. However, imposing the common support is also expected to reduce the bias of the estimators since it ensures that the treated and untreated firms are comparable.

The second set of results is depicted in table 3. In this case, the effect of around 9 percent on investment / capital becomes significant at 1 percent level. The impact on employment and labor productivity seem to be robust and increase slightly to 17 percent and 16 percent respectively. The effect on number of products also increases but it is now only significant at 10 percent. The coefficients by year of treatment show very similar values compared to the previous results, but in general with higher standard errors. As a result, many of them turn insignificant on the matched sample. However, this robustness check suggests that the bias in the previous results is small.

Finally, a further robustness check consists on adding to equation (2) dummy variables for future participation, for instance, a dummy taking the value of one on the year previous to the entry to the program. If the identification assumption of parallel ex-ante trends is met, then these variables should be insignificant. In fact, since the program cannot have an effect on the outcome before participation, the significance of one of these variables would suggest that the treatment dummies are capturing differences between treated and untreated groups other than participation that are not being accounted for. The results of this robustness check are presented in table 4. The lead-dummy variables are significant at 10% level for employment, suggesting that some unobserved time-varying differences between groups could be biasing the coefficients for this outcome. However, the lead variables are insignificant for the other outcomes.

6. Conclusions

This paper aims at evaluating the impacts of innovation promotion programs administrated by the Colombian Innovation Agency (COLCIENCIAS). Although the agency implements multiple

programs, the focus of these research are on those programs that provide financial incentives for R&D (matching grants and contingent loans) and at the same time encourage the formation of linkages between firms, universities and other public research organizations. Different from previous evaluations, a nice feature of the current research is the possibility to use a very rich dataset in order follow-up the economic performance of the beneficiaries over a long period of time. The results show that after controlling for both observable and unobservable difference with the control group, COLCIENCIAS programs have been very effective in increasing firm labor productivity and that the main channel behind this result is product diversification (product innovation). Impacts on employment and capital investments are more modest thought, suggesting that the mail transmission channel is through total factor productivity.

The importance of these results is twofold: first they confirm that TDF are effective not only in promoting innovation at the firm level (through the introduction of new products), but also in boosting firms' performance in the long run. Secondly they show that longer-term impact evaluations of such projects enable the detection of impacts on some of the most relevant variables of interest. This does not necessarily mean that final impact evaluations should be carried out five years after the project's execution. Evaluations could focus instead on the first cohorts of treated firms, so that by the end of a program some results on performance could also be assessed. This is precisely the approach taken by the US Congress for the evaluation of the Small Business Innovation Research (SBIR) program. The moment the program was approved in the early 1980s, Congress asked the Small Business Administration (SBA) to ensure that beneficiaries of the first three cohorts be followed up over the next decade (Lerner, 2002).

Table 2: Baseline Estimates, Full Sample.

	Investment / capital		Ln(employment)		Ln(labor prod)		Number of products	
COLCIENCIAS	0.034		0.126**		0.153***		0.093**	
	[0.029]		[0.056]		[0.045]		[0.043]	
1st year		0.041		0.122*		0.056		0.062
		[0.047]		[0.062]		[0.048]		[0.040]
2nd year		0.031		0.103*		0.139***		0.096**
		[0.054]		[0.060]		[0.052]		[0.041]
3rd year		0.178		0.172**		0.123**		0.105**
		[0.121]		[0.069]		[0.055]		[0.050]
4th/5th years		-0.010		0.175***		0.170***		0.110**
		[0.047]		[0.061]		[0.055]		[0.054]
6th/7th years		-0.037		0.104		0.092		0.092
		[0.059]		[0.085]		[0.089]		[0.069]
8th/+ years		-0.010		0.133		0.253**		0.091
		[0.086]		[0.157]		[0.114]		[0.091]
Fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Time dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	84,208	84,208	84,910	95,963	84,910	95,963	84,950	96,014
Number of firms	10,470	10,470	10,548	11,313	10,548	11,313	10,551	11,318

Source: Own calculations.
Note: * Coefficient is statistically significant at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level; no asterisk means that the coefficient is not different from zero with statistical significance. Robust standard errors in brackets.

Table 3: Baseline Estimates, Common Support Sample

	Investment / capital		Ln(employment)		Ln(labor prod)		Number of products	
COLCIENCIAS	0.087***		0.159**		0.149**		0.124*	
	[0.033]		[0.077]		[0.064]		[0.068]	
1st year		0.090		0.145		0.045		0.079
		[0.059]		[0.101]		[0.068]		[0.068]
2nd year		0.079		0.117		0.126*		0.112*
		[0.058]		[0.099]		[0.075]		[0.068]
3rd year		0.217*		0.168*		0.104		0.125*
		[0.114]		[0.100]		[0.068]		[0.074]
4th/5th years		0.042		0.173*		0.146**		0.133*
		[0.060]		[0.091]		[0.071]		[0.080]
6th/7th years		0.040		0.102		0.092		0.135
		[0.073]		[0.112]		[0.095]		[0.091]
8th/+ years		0.047		0.090		0.301**		0.151
		[0.098]		[0.160]		[0.135]		[0.111]
Fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Time dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Common support			*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	36,355	36,356	36,468	39,409	36,468	39,409	36,473	39,415
Number of firms	2,997	2,998	2,997	2,997	2,997	2,997	2,997	2,997

Source: Own calculations.
Note: * Coefficient is statistically significant at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level; no asterisk means that the coefficient is not different from zero with statistical significance. Robust standard errors in brackets.

Table 4: Robustness Checks, Common Support Sample

	Investment / capital	Ln(employment)	Ln(labor prod)	Number of products
1st year	0.081	0.174	0.044	0.102
	[0.060]	[0.115]	[0.076]	[0.082]
2nd year	0.071	0.145	0.126	0.134*
	[0.059]	[0.113]	[0.081]	[0.079]
3rd year	0.208*	0.196*	0.104	0.148*
	[0.116]	[0.114]	[0.075]	[0.086]
4th/5th years	0.034	0.202*	0.146*	0.156*
	[0.062]	[0.105]	[0.077]	[0.091]
6th/7th years	0.031	0.130	0.091	0.158
	[0.074]	[0.125]	[0.100]	[0.101]
8th/+ years	0.038	0.119	0.301**	0.173
	[0.099]	[0.169]	[0.138]	[0.119]
Lead 1	-0.082	0.163*	-0.031	0.132
	[0.070]	[0.093]	[0.073]	[0.085]
Lead 2	-0.004	0.120*	0.022	0.093
	[0.037]	[0.068]	[0.063]	[0.086]
Fixed effects	*Yes*	*Yes*	*Yes*	*Yes*
Time dummies	*Yes*	*Yes*	*Yes*	*Yes*
Common support	*Yes*	*Yes*	*Yes*	*Yes*
Observations	36,268	39,409	39,409	39,415
Number of firms	2,997	2,997	2,997	2,997

Source: Own calculations.

Note: * Coefficient is statistically significant at the 10 percent level, ** at the 5 percent level, *** at the 1 percent level; no asterisk means that the coefficient is not different from zero with statistical significance. Robust standard errors in brackets.

References

Aschhoff, B. 2009. “The Effect of Subsidies on R&D Investment and Success – Do Subsidy History and Size Matter?” ZEW Discussion Paper No. 09-032, Mannheim.

Aghion, P., P. David and D. Foray. 2009. “Science, Technology and Innovation for Economic Growth: Linking Policy Research and Practice in STIG Systems”. *Research Policy*, 681-693.

Arrow, K. 1962. “Economics Welfare and the Allocation of Resources for Invention.” in R. Nelson (ed.), *The Rate and Direction of Inventive Activity*, Princeton University Press, pp. 164-181.

Benavente J. M., Crespi G. and A. Maffioli. 2007. “Public Support to Firm Innovation: The Chilean FONTEC Experience”. OVE Working Papers 0407, Inter-American Development Bank, Office of Evaluation and Oversight (OVE).

Binelli, C. and A. Maffioli. 2007. “A Micro-econometric Analysis of Public Support to Private R&D in Argentina”. *International Review of Applied Economics,* Taylor and Francis Journals, vol. 21(3), pp. 339-359.

Cimoli M. and G. Dosi. 1995. “Technological Paradigms, Patterns of Learning and Development. An Introductory Roadmap”. *Journal of Evolutionary Economics*, 5 (3): 243-268.

Chudnovsky, D., A. López, M. Rossi and D. Ubfal. 2006. "Evaluating A Program of Public Funding of Private Innovation Activities. An Econometric Study of FONTAR in Argentina," OVE Working Papers 1606, Inter-American Development Bank, Office of Evaluation and Oversight (OVE).

Czarnitzki, D. and A. Fier (2002), “Do innovation subsidies crowd out private investment? Evidence from the German service sector.” Konjunkturpolitik – Applied Economics Quarterly 48(1): 1-25.

Czarnitzki, D. and K. Hussinger. 2004. “The Link between R&D Subsidies, R&D Spending and Technological Performance.” ZEW Discussion Paper No. 04-56, Mannheim.

David, P., B. Hall and A. Toole. 2000. “Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence.” *Research Policy*, 29, pp. 497-529.

De Negri, J.A., M. Borges Lemos and F. De Negri. 2006a. "The Impact of University Enterprise Incentive Program on the Performance and Technological Efforts of Brazilian Industrial Firms." OVE Working Papers 1306, Inter-American Development Bank, Office of Evaluation and Oversight (OVE).

----. 2006b. "Impact of P&D Incentive Program on the Performance and Technological Efforts of Brazilian Industrial Firms," OVE Working Papers 1406, Inter-American Development Bank, Office of Evaluation and Oversight (OVE).

Dosi, G. 1988. "Sources, Procedures, and Microeconomic Effects of Innovation". *Journal of Economic Literature*, American Economic Association, 26(3); 1120-71, September.

Dosi C., C. Freeman, R. Nelson, G. Silverberg and L. Soete, editors. 1988. *Technical Change and Economic Theory*, London: Pinter

Dosi, C. and Nelson, R., editors. 1994. “An Introduction to Evolutionary Theories in Economics.” *Journal of Evolutionary Economics*, Vol. 4 (3), pp. 153-172.

Fier, A, 2002. Staatliche Förderung industrieller Forschung in Deutschland: Eine empirische Wirkungsanalyse der direkten Projektförderung des Bundes, Baden-Baden: Nomos-Verl.-Ges.

González, X., J. Jaumandreu and C. Pazo. 2005. "Barriers to Innovation and Subsidy Effectiveness." *RAND Journal of Economics*, The RAND Corporation, vol. 36(4), pages 930-949, Winter.

Gonzalez, X., and C. Pazo. 2008. Do public subsidies stimulate private R&D spending? *Research Policy*, 37(3): 371-389.

Hall, B. and J. Van Reenen. 2000. “How effective are fiscal incentives for R&D? A review of the evidence.” *Research policy*, 29 (4-5.). pp. 449-469.

Hall, B. and A. Maffioli. 2008. “Evaluating the Impact of Technology Development Funds in Emerging Economies: Evidence from Latin America.” NBER Working Paper No. 13835, National Bureau for Economic Research, Cambridge, MA.

Hussinger, K. 2008. “R&D and Subsidies at the Firm Level: An Application of Parametric and Semi-Parametric Two-Step Selection Models.” *Journal of Applied Econometrics* 23: 729-747.

Klette, T. J., M. Jarle and Z. Griliches. 2000. "Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies". *Research Policy*, Elsevier, vol. 29(4-5): 471-495, April.

Lach, S. 1999. “Labor Productivity in Israel’s Manufacturing Industry, 1990-1994”. *Bank of Israel Economic Review*, 72:23-49, November.

Lach, S. 2002. “Do R&D subsidies stimulate or displace private R&D? Evidence from Israel.” *Journal of Industrial Economics* 50(4), 369-390.

Lerner, J. 1999. The government as venture capitalist: The long-run impact of the SBIR program. *Journal of Business*, 72(3), 285–318.

Lerner, J. 2002. When bureaucrats meet entrepreneurs: The design of effective ‘‘public venture capital’’ programmes. *Economic Journal*, 112(477), F73–F84.

Levin, R., A. Klevorick, R. Nelson and S. Winter. (1987) “Appropriating returns from industrial research and development.” *Brookings Papers on Economic Activity* 3, pp. 783–831.

Licht G. and M. Stadler. 2003. Auswirkungen öffentlicher Forschungsförderung auf die private F&E-Tätigkeit: Eine mikroökonometrische Evaluation, in: Franz, W., H.J. Ramser and M. *Stadler*, editors. *Empirische Wirtschaftsforschung, Methoden und Anwendungen*, Wirtschaftswissenschaftliches Seminar Ottobeuren, Vol 32, Tübingen, 213–239.

Lopez-Acevedo, G. and H. Tan. 2010. “Impact Evaluation of SME Programs in Latin America and the Caribbean.” The International Bank for Reconstruction and Development / The World Bank, Washington, D.C.

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., editor. 1992. *National System of Innovation: Towards a Theory of Innovation and Interactive Learning*, London: Pinter.

Martin S. 2000. “The Evaluation of Strategic Research Partnerships.” *Technology Analysis & Strategic Management*, 15/2: 159-176

Mansfield, E., M. Schwartz and S. Wagner. 1981. “Imitation Costs and Patents: An Empirical Study.” *Economic Journal* 91, pp. 907-918.

Martin S. and J. Scott. 2000. “The Nature of Innovation Market Failure and the Design of Public Support for Private Innovation.” *Research Policy*, 12, 437-447.

Mercer-Blackman, V. 2008. “The Impact of Research and Development Tax Incentives on Colombia’s Manufacturing Sector: What Difference Do They Make?” IMF Working Paper WP/08/178.

Metcalfe J.S. 1994. “Evolutionary Economics and Technology Policy.” *The Economic Journal*, 104, pp. 931-944.

Morgan K. 1996. “Learning by interacting: inter-firm networks and enterprise support.” in OECD (ed.), *Network of enterprise and local development*, OECD Publication, Paris.

Nelson, R. 1959. “The Simple Economics of Basic Scientific Research.” *Journal of Political Economy* 67(3), pp. 297-306.

Nelson, R. and S. Winter. 1982. *An Evolutionary Theory of Economical Change*, Cambridge, MA and London: Harvard University Press.

Powell W., K. Koput and L. Smith-Doerr. 1996. “Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology.” *Administrative Science Quarterly*, 41:116-145

Teubal M. 1998. Marco de Políticas para el Financiamiento de la Innovación en economías en vías de Industrialización, SDS Working Paper.