Effects of public funding on private innovation behaviour: evidence from Latin America.

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Abstract:

A comprehensive assessment of the effects of innovation policy in the innovation dynamics at firm level embraces several dimensions. One of them are the effects of public support on firms' behaviour, which has been analysed from different policy rationales. However, despite the large theoretical and the methodological improvements, empirical evidence is not conclusive. Actually, the effects of public innovation programs show heterogeneous results by firm, sector, country and type of innovation. This paper assesses the effects of public policy in a Latin American country during a period of policy reform. It assesses the input and behavioural additionality of public funding on private innovative investment of Uruguayan firms by applying a longitudinal analysis from 2003 to 2012. During this period, there was a dramatic increase of public innovation funds. However, the number of innovative firms remained stable and the amount of public funding for innovation at firm level was still very low. Our results show evidence of additionality effects of public funding on private investment. However, these effects are heterogeneous according to firms' characteristics and the type of innovation activity conducted by the firm. We find additionality for innovation based on acquisition of artefacts (embodied) in SMES. In the same vein, behaviour additionality estimates report significant effects of public support on the expansion of the productive capacity. Our results show that innovation public funding seems to reinforce the traditional innovation pattern in Latin American countries, strongly based on embodied innovation activities and concentrated in a small proportion of national firms. It allows us to discuss the main challenges for national innovation policies in middle-income countries.
Keywords: public funding; additionality, panel data, Uruguay

JEL classification: O3, O38, L2; H81

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1. Introduction

Applying different theoretical backgrounds and empirical strategies, economic researchers have studied the effects of public support on the private investment and innovation behaviour of the firms (Becker 2015; Zúñiga-Vicente et al. 2014; García-Quevedo 2004; David et al. 2000). By using accurate econometric techniques and panel databases, different methodological biases have been progressively corrected, which improved the results obtained (Cunningham et al. 2013).

Nevertheless, empirical findings are far from being conclusive and results still show heterogeneous effects both in developed and developing countries (Szczygielski et al. 2017; Crespi et al. 2016; Marino et al. 2016). The basic question about complementarity or substitution effects of public support on private investment has found heterogeneous answers by firm, sector and country characteristics. The intensity of these effects has also been diverse (Zúñiga-Vicente et al. 2014; Cunningham et al. 2013). Hence, further research assessing mixed effects through longitudinal analysis is necessary.

Moreover, several works on firm innovation behaviour have considered different type of innovation activities distinguishing between innovation activities based on R&D or not (Santamaría et al., 2009; Rammer et al. 2009); or between technological and organizational innovations (Camisón and Villar-López 2011; Battisti and Stoneman 2010). However, most of the empirical studies have been focused on public support for R&D, disregarding other innovation activities. The distinction between different types of innovation activities makes it possible to identify different innovation patterns associated with different appropriability conditions, technological risks and the internal capabilities required to conduct the innovation projects (Crespi et al. 2016). Particularly, to distinguish between activities based on R&D or technology reception (disembodied innovation) and the acquisition of technological knowledge embodied in goods and devices (embodied innovation) (Cassiman and Veugelers 2000), allows a general proxy to the innovation strategy of the firm.

However, why is it relevant to assess additionality or substitution effects of public findings on firms' innovation investment? We elaborate on the use of additionality assessment of public funding as a measure of the extent to which policy goals have been achieved. In this regard, we discuss the market failure rationale of public funding for innovation by opposing a more realistic and complementary approach to the rationale behind innovation policies in developing countries. This rationale is based on the idea that, in developing countries, innovation policies face the big challenge to affect the firm behaviour by introducing new incentives to innovate. Therefore, rather than fixing some supposed market failures, innovation policies have as their ultimate goal to incentive innovative activities and the engagement of private firms in innovation.

In this sense, we analyse the effect of public funding in the innovative behaviour (behavioural additionality) of the firm (Neciu et al. 2016; Falk 2007). This allows us to accomplish the main objective of the paper: to conduct a comprehensive assessment of the effects of public funding on innovative firm behaviour.

We conduct a longitudinal analysis using the Uruguayan Innovation Survey (UIS) from 2003 to 2012. This period includes a recession, crisis and the subsequent recovery process of the Uruguayan economy. Moreover, during these years it is possible to identify three phases of the innovation public policy; starting from an almost negligible public intervention on private innovation up to a dramatic increase in the public support for innovation.

The main questions of the paper are: What are the effects of public innovation support in Uruguayan firms? Is there any evidence of input additionality? Are there heterogeneous effects according to the size of the firm or the type of innovation activity carried out by the firms? Have supported firms changed their innovative behaviour as a result of public support?

We run a linear estimation of additionality using the panel structure of the dataset including fixed effects by time and firm. Moreover, we estimate the elasticity of private innovation investment to public innovation funding by applying a log-linear estimation of the previous model. Looking for heterogeneous effects, we applied the same models to estimate the incidence of public support on private investment in embodied and disembodied innovation activities. In addition, we extend our model to test effects of public support on internal and external dimensions of innovative behaviour.

In accordance with the changes experienced in public policy, our results show a dramatic increase of the number of firms that received public support for innovation activities since 2006. However, the amount of public support for innovation investment at firm level remains low and the total amount of investment seems stable after 2003. Econometric estimates show additionality effects between private and public funds. We find heterogeneous effects of public funding since we only identify input for firms that conduct embodied innovation activities. Also, our additionality estimates are higher for small firms. In contrast, the estimates of behavioural additionality show that public support has not had significant effects on the innovative behaviour of firms.

These results draw a general landscape of the innovative dynamics in the Uruguayan economy during the last decade. A big national effort on innovation policy has reinforced a pattern where the critical mass of innovative firms remain stable and innovation activities are mostly devoted to enhance their productive capacity through investment in capital goods. This situation is not a Uruguayan anomaly but many of these features sketch out a pattern of Latin American emerging economies (Crespi et al. 2016; Rocha 2015; Chudnovsky et al. 2006). Therefore, this paper aims to discuss policy challenges beyond the specific national case.

2. Theoretical framework

2.1. Towards a comprehensive approach of innovation policy rationale in developing countries

Arguably, the milestone of the current mainstream innovation policy is the concept of market failures (Takalo et al. 2013; Binelli and Maffiolli 2007; David et al. 2000). The rationale of both the policy as a whole and the specific instruments or programs are usually based on the question: What is the market failure(s) that the policy (instrument) aims to correct? (Klette et al. 2000). This question arises from the appropriability failures of knowledge early stressed by Nelson (1959) and Arrow (1962), and states that policy intervention is only justified when market mechanisms do not work.

This rationale, has received several criticisms from political economy, institutionalist and evolutionist points of view (Mazzucatto 2016; Srinivas 2012), which stress that market failure approach offers useful insights to guide innovation policies oriented to correct markets that already exist. However, it does not offer a theoretical rationale to create new market when they do not exist (Mazzucatto 2016).

The call for a rationale of innovation policy oriented to create market mechanisms is particularly relevant in small developing countries, where innovation activities are unusual and innovation policies are in early phases. However, the market failure approach offers simple criteria to analyse firms' behaviour under market mechanisms (Bleda and Del Rio 2013). Therefore, a comprehensive assessment of innovation policy effects on firm's innovative behaviour should embrace the additionality effects as an indicator of the general effect of policy mix rather than a result itself (Neicu et al. 2016).

As Chaminade and Edquist (2010: 95) have pointed out, innovation policy is a question of the division of labour between governments, private and public firms, organizations such as research institutes and, highly relevance in developing countries, international financial institutions and multilateral organisations. There are different features of this labour division, which in turn involve different objectives and practices. Nevertheless, a common place in innovation policies is the government purpose to influence the behaviour of firms not engaging in innovation activities and to guide innovative firms to follow an innovative path looking for positive economic results. It should be noticed that this schematic classification, a basic common sense principle of public policy, is particularly relevant in developing middle-income countries such as the Southern Cone countries. These countries show a chronic weakness of productivity and innovation dynamics characterized by a small critical mass of innovative firms, which in turn affects feedback mechanisms of development and structural change (Yoguel and Robert 2010; Crespi and Zuniga 2013; Vivarelli et al. 2014). However, during the last decade, Southern Cone countries have experienced one of the longest periods of economic growth based on natural resource exploitation (CEPAL 2012). In this context, the innovation policy goals oriented to change firms' behaviour is arguably the hardest policy challenge. Why do firms conduct innovation activities under the high uncertainty of results? Particularly, why do they conduct them when regular activities are profitable?

In sum, the ultimate challenge is not to correct a failure in a market that is not working properly. It is to change the behaviour of economic agents to do something different, in many cases in spite of short run economic rationale, to participate in new and more uncertain markets. In this context, innovation policy rationale should be considered in a comprehensive and realistic framework, which includes the analytical toolkit of market failures approach in order to analyse the effects of policy as a whole.

2.2. Types of innovation policies and instruments

Public policies oriented to promote innovation conform a more or less articulated set of policy measures recently named as policy mix. Theoretically, a policy mix should include different types of policies (Borrás and Edquist 2013; Flanagan et al. 2011) which in turn have different instruments that should show interactive effects (Cunningham et al. 2013b). Hence, within a policy mix is expected to find policies focused on both specific and general targets (mission or diffusion oriented policies). The target of these policies can be defined by a general rationale, such as appropriability market failures for diffusion-oriented policies, while mission oriented policies can be based on a strategic assumption, such as the promotion of a strategic activity, rather than on a general rule (Köhler et al. 2013).

Moreover, policies are classified according to the mechanism used to deliver public support (subsidies, tax credit, pre-commercial technological procurement, associative funding). Polices based on compulsory regulations (*stick type instruments)* define rules that promote innovation and the enforcement mechanism to implement it (e.g. environmental regulation for clean technologies). Another type of policy, and the most extended in Latin America, is based on incentives (*carrot type instruments*), mainly financial support (e.g subsidies, tax credit, loans). Finally, it is possible to recognise policies based on instruments like national awards, honours or other symbolic recognitions (*sermon type instruments*) (Borrás and Edquist 2013; Bemelmans-Videc et al., 1998).

This paper is focused on a particular type of policies –diffusion oriented – delivered through financial incentives and, specifically, through subsidies to the firms.

From a mainstream rationale, subsidies try to stimulate private innovative investment by reducing private uncertainty and costs. Due to market failures associated with a lack of appropriability and the derived externalities, innovation investment is highly uncertain and social return exceeds private benefits (Hall and Lerner 2010).

The effects of subsidies on firms' innovative conduct can be observed through changes in the financial effort of the firms (input additionality); changes in internal and external knowledge related activities (behavioural additionality) and changes in the innovation results achieved by the firms (output additionality). This paper assesses both the input and the behavioural effects of innovation subsidies.

To assess the degree up to which subsidies promote input additionality it is necessary to observe the innovation investment of supported firms. The increase in the amount of private investment made by supported firms can be equal to the amount of subsidy, in that case nor additionality neither substitution effects are observed. Moreover, firms can use public funds in order to finance fixed costs, covering variable costs with their own funds. In this scenario additionality is observed, public support boosts private investment that increases by an amount that exceeds the amount of public funds. The opposite scenario, substitution, is also likely: firms can receive funding for projects that they would have carried out regardless of public support. In this setting, firms would substitute private funds with public funds. When the increase in private innovation investment is equal to 0 we observe a full substitution or crowding out effect. However, if private investment increases by an amount that is lower than the subsidy, we observe a partial substitution effect (Crespi et al. 2011; David et al. 2000).

From a comprehensive policy rationale it does not really matter if input additionality is observed by itself. As it was mentioned before, we consider it to be an indicator of changes in the innovative behaviour of firms (Neicu et al. 2016). The effects of policy support in the innovation strategies of firms can be observed also through other complementary indicators. In this regard, economic literature has paid attention to the behavioural additionality effects on organizational learning process (Clarysse et a. 2009); complementarities between innovation activities (Hall & Maffioli 2008; Benavente et al. 2007); building internal capabilities (Antonioli et al. 2012; Gök & Edler 2012), and the expansion of external knowledge sources and collaborative innovation linkages (Okamuro & Nishimura 2015; Benavente et al. 2007).

The study of behavioural additionality is particularly relevant in developing countries where national policy efforts are incipient and usually oriented to foster innovation outputs of already innovative firms but also to diffuse innovative practices and collaborative relations. Moreover, behavioural additionality captures the incidence of public effort on practices and actions that firms incorporate in their routines (Hall & Maffioli 2008; Crespi et al. 2011) offering a suitable proxy indicator of sustainability of policy effects within the firm.

Theoretical propositions on additionality effects of public funding have been widely tested in empirical studies (Becker 2015; Zúñiga-Vicente et al. 2014; García-Quevedo 2004; David et al. 2000). Recent literature has improved the additionality estimates finding a moderate convergence to reject the hypothesis of crowding out effects in developed countries (Cunningham et al. 2013a). However, this trend is not observed in other countries, Simachev et al (2015) report crowding-out effects for public innovation funding in Russia. In Latin America, Binelli and Maffioli (2007) found complementary effects of public support, with a positive elasticity higher than 1 between public funding and private investment. However, Chudnovsky et al. (2006a) only found evidence of partial additionality when analysing the same policy instrument. Benavente et al. (2007), using the same methodology than Chudnovsky et al. (2006a), also found evidence of partial additionality when analysing a Chilean innovation program.

Moreover, empirical evidence shows highly heterogeneous effects (Becker 2015). Zúñiga-Vicente et al. (2014) show that public funding effects are different according to the 'public support history of the firm'. Firms that have received early support are more likely to present substitution effects. However, in sectors where innovation is very expensive and private funds are scant, early supported firms show higher complementary effects. Other studies found that the relationship between public funding and private innovation investment can be described as an inverted U shaped function. In this case, higher public funding will spur additional private investment up to a threshold where, either because the firm resources are fully employed or because risk is too high, private investment is substituted by public funding (Becker 2015; Zúñiga-Vicente et al. 2014). However, there is evidence that shows how in some sectors there is an absolute threshold. This threshold is determined by the absence of capital markets, which defines the minimum public funding level that allows private innovation investment (Hyytinen & Toivanen 2005).

Moreover, Cunningham et al. (2013) and Köhler et al. (2013) highlight that the evaluation works from OECD countries show heterogeneous results of public innovation funding according to firm, sector and the country's relative level of industrial development. In addition, large firms could face less severe financial restrictions than small ones, increasing additionality for minor firms. Crespi et al (2016) found a non-significant effect of tax credit for innovation in high-tech SMEs in Argentina. This is an unexpected result since that the target of public funding is to reduce the investment gap that affects firms that conduct riskier investments. Kannebley and De Prince (2015) show similar results for Brazil. They highlight that tax credits for innovation, which supposedly operate on the financial restriction of the firm, have achieved little result on some target population -SMEs and high-tech firms-. Both, Crespi et al. (2016) and Kannebley and De Prince (2015), stressed that despite the appropriability problems, the innovation activities based on R&D are relatively more complex than others based on external acquisition of embodied technology. Hence, the capabilities of the firm can operate as an internal barrier non related to capital restriction or appropriability problems.

In this regard, heterogeneous effects by type of innovation activities is particularly likely. A basic distinction between innovation activities based on R&D – internal and external – (*disembodied innovation activities*) and others based on the acquisition of capital goods and tangible technologies (*embodied innovation activities*) is particularly useful to analyse the effects of public funding in a comprehensive view of behavioural innovation of the firms. Several authors have stressed that embodied and disembodied innovation are related to different innovation strategies (Cassiman and Veuguelers 2000) and that they have different effects on firms growth and employment (Barbieri et al. 2016).

Due the presence of approapriability failures, disembodied innovation usually faces higher risk than embodied innovation (Bontempi 2016; Crespi et al. 2016). Hence, the effect of public funding on the former shoud be higher than for the latter. However, the opposite could occur due to embodied innovation being more elastically supplied than disembodied innovation. For example, Crespi et al. (2016) found additionality effects of Argentinean tax credit programs only for embodied innovation activities.

3. Innovation and public policies in Uruguay

From the policy side, during the last decade, Uruguay has built the first national innovation policy. New instruments and programs have been implemented under a new institutional framework. Moreover, public investment on innovation activities has grown in six times since 2008. However, the national effort on innovation support and the amount of regular innovation projects are lower compared to the region (Aboal et al. 2014).

It is possible to identify three sub-periods of innovation policies from 2000 to 2012. First, a period that can be defined as ad hoc innovation policies (2000-2006), where there were a little number of innovation programs, mainly concentrated around the first technological programs supported by the IADB. After that, from 2007 to 2012, there was a re-building and experimentation process, were old and new programs were implemented. The last phase, since 2012 up to the present, shows a proto–system of innovation policies, where even in an incipient phase Uruguay has a large number of instruments to promote innovation activities.

From the side of the productive sector, the Uruguayan economy shows a low innovation propensity. Since the first available measurement in 1985, the percentage of industrial firms that have conducted at least one innovation activity remained stable around 30% (ANII 2014; Bianchi 2007). Within the innovative firms, innovation activities embodied in capital goods are the most frequent (ANII 2014). However, several works show the incidence of innovation activities conducted by Uruguayan firms in productivity (Aboal & Garda 2016), in the creation of highly skilled workplaces (Zuniga & Crespi 2013).

Moreover, there are a number of studies that evaluate the effect and impact of innovation policies since 2006. They show that received public support have invested more in innovation activities than the innovative firms that did not receive public support (ANII 2014). These authors offer significant evidence of positive effects of innovation policies in economic performance of the firms. Aboal and Garda (2015) find additionality effects of public support on private innovation investment. However, they do not observe new effects on early innovator nor productivity gains associated to public innovation support.

These studies contribute by offering robust impact evaluation of specific programs during a short period. However, they do not address a comprehensive assessment of public funding support on innovative behaviour of firms.

4. Methodology

This paper aims to assess the effects of public funding on innovative behaviour of Uruguayan firm between 2001 and 2012. In doing so, it addresses four specific objectives: i) to estimate input additionality effects of public funding on private investment; ii) to estimate heterogeneous input effects of public support on private innovation investment; iii) to assess behavioural additionality effects of public funding on supported firms and iv) to analyse the stylised facts related to the different phases of the national innovation policy.

According to previous works, we pose that it is possible to identify changes after the recent innovation policy reform. Regarding the increment of public budget devoted to innovation programs, we expect to find a crowding-in effect of public funding on private innovation investment.

H1: There are additionality effects of public funding on the private innovation investment in the Uruguayan firms between 2001 and 2012.

Moreover, regarding the risk and cost of innovation project based on R&D we expect to find a more intensive additionality effect of public funding on private investment in disembodied innovation activities.

H2: There are heterogeneous effects of public innovation support. The firms engaged on disembodied innovation activities show more intensive additionality effects than those engaged on embodied innovation activities.

Finally, considering complementarity observed between different types of innovation activities and the systemic nature of the innovation process, we expect a positive effect of public funds on process and organizational innovation activities and in external collaborative linkages.

H3 There are significant behavioural additionality effects of public innovation support on he supported firms

4.1. Data

To test these hypotheses we use a unique database, which contains information from multiple datasets. The main sources are four Uruguayan Innovation Surveys (UIS), triennial surveys that cover the period 2001–2012. These surveys contain cross-sectional information on manufacturing firms for the entire period. Firms belonging to the services sector are included to the survey in 2006. The sample of the UIS is representative of all firms with five employees or more. We merged the four surveys in order to obtain an unbalanced panel dataset using unique firm identifiers provided by the National Agency of Research and Innovation (ANII by its Spanish acronuym).

Previous works have used innovation survey data to assess additionality of public innovation policies. Many of them apply quasi-experimental econometric techniques (Bodas Freitas et al. 2017; Marino et al. 2016) while others use elasticity estimation functions (Klette et al. 2000). However, as is well known, innovation survey data should be used carefully to assess policy effects (Mairesse & Mohnen 2010). Many criticisms on innovation survey are focused on the self-reported data condition, which can create unobservable biases. In this regard, the use of instrumental variables appears as a suitable option (Bontempi 2016). However, self- reported data is inherent to almost any survey collected data in economics, which does not invalidate its use, albeit in a cautious way.

Regarding our dataset, we have two potential sources of biases. Firstly, using the UIS it is only possible to distinguish different programs after the third wave (2006-2009). Therefore, we can only work with information about the percentage of public support on the innovation budget of the firm. Secondly, since the final sample is not properly representative, potential biases require careful treatment and limitations of the obtained estimates must be explicit.

Data from the UIS is complemented with data from the Annual Survey of Economic Activity (ASEA), which provides supplementary information on employment, capital formation, input costs and salaries. These surveys are representative of all firms with 10 employees or more[1]. We are able to merge both datasets using common identifiers provided by the National Institute of Statistics (INE by its Spanish acronym).

Combining all UIS surveys (merged with information from the ASEA) –after some cleaning and removing of outliers[2]– leads to a dataset of 3,296 observations from 1,779 firms. Since our empirical strategy requires panel information, we construct our main dataset only including innovative firms that appear at least twice (not necessarily consecutively) in UIS surveys compose our main dataset. This leads to 1,094 observations of 414 firms[3].

The panel structure of the dataset is crucial for our empirical strategy, since it allows controlling for time-invariant unobservable characteristics of firms while providing a rich set of time-varying observable characteristics. Nevertheless, it is important to stress that, because of the cross-sectional nature of the UIS; the resulting panel ceases to be representative. This occurs since the probability of appearing more than once in our panel dataset is not uniform across firms. On the contrary, it is positively correlated with firms' size and, indirectly, with their innovation propensity. Therefore, descriptive statistics and model estimates should be interpreted regarding the sample population. The panel structure of our dataset can be seen in Table 1.

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[2] Specifically, we delete 44 observations from 15 firms that report innovation investments that are larger than the 99th percentile. These are mainly public companies or private firms that have received very significant foreign direct investment between 2005 and 2012.

[3] The number of observations increases to 1,604 from 625 firms when including firms that do not appear in the ASEA. We use this larger sample in order to carry out robustness checks.

However, the severity of this bias should be nuanced. Innovative firms are usually larger than non-innovative. Since we focus on innovative firms, the attrition bias is reduced; because smaller firms are partially excluded from our analysis[4].

[Table 1 near here]

The average firm in our dataset has 269 employees and an annual turnover of 360 million Uruguayan pesos of 2005 (approximately 14 million American dollars of 2005). 83% of firms employ more than 50 employees. In order to measure the amount of attrition bias, we compare these summary statistics to those obtained when considering the pool of innovative firms in all four UIS. In this latter dataset, firms on average employ 117 workers, only 39% of them have more than 50 employees and their average annual turnover is 60% smaller than in our working dataset. In addition, the technological intensity of firms[5] is higher in our sample (20% are in high technology sectors) than in the pool of innovative firms (12%).

4.2. Dependent and explanatory variables

Our main dependent variable is the amount of money invested on innovation activities. The explanatory variables are i) an indicator if the firm received public financial support for innovation and ii) the amount of public money received by the firm for innovation activities. Furthermore, in an extension of our model, we estimate the behavioural additionality effects of public support. This implies modifying our dependent variables to three indicators related to the innovation strategy of firms: i) the introduction of

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4 This is because the questionnaire is designed to only report information on innovation related questions for innovative firms.

5 We define high technology aggregating the categories "high-technology" and "medium-high technology" in the classification of the OECD (OECD, 2011).

process or organisational innovations, ii) the relevance of process or organisational innovations and iii) the level of cooperation that the firm has with the national system of innovation (NSI). In this subsection, we briefly summarize the method for constructing dependent and explicative variables.

Before 2009, the survey did not include questions regarding public support. Nevertheless, firms had to declare the percentage of funds used to finance innovation activities disaggregated by source: own source, external private sources and public sources. We define that a firm received public support if it declares a positive percentage of funds from the public sector. Furthermore, we calculate the amount of public support received by multiplying the former percentage to the declared investment in innovation activities. In the last two surveys, no recoding is required given that a specific question on whether the firm received public support and the amount received (if any) is included. It should be noted that we are not able to distinguish between policy instruments, a relevant caveat considering the variety of current innovation programs in Uruguay and the different objectives and rationales that each program follows.

Finally, in order to estimate heterogeneous effects of policies according to different types of innovation we consider the amount of money invested on innovation activities distinguishing between investment in disembodied innovation activities (R&D, internal and external, and reception of technology transfer), and investment in embodied innovation activities (acquisition of knowledge in the form of capital goods or ICT).

We use eight different dependent variables in the extended behavioural model. Firstly, we use dummy variables that indicate whether the firm declares having adopted any process innovation (1) and any organisational innovation (2). Secondly, we use a categorical variable that measures the self-reported relevance of the process innovations adopted by the firm (3) and the training activities carried out by it (4). Each firm classifies the relevance of their innovations in an ordinal scale that goes from 1 (highly relevant) to 4 (irrelevant) in 14 different aspects. Based on Benavente et al. (2007), we define (3) through the following formula:

$$relev\_proc_{i,t} = \frac{1}{4 * n_{proc}} \sum_{k=1}^{n_{proc}} relev_{i,t,k}$$

where n_{proc} is the number of specific issues related to process innovations (5: productive capacity, productive flexibility, labour costs, input consumption and energy consumption) and $relev_{i,t,k}$ is the declared relevance of the issue *k* to firm *i* in year *t*. The former index ranges from the value 0.25 if the firm declares that innovative activities were highly relevant (1) for all issues and 1 if they were irrelevant (4) for all issues. No further coding is needed. We measure the interactions with the NSI using two dummy variables that indicate whether the firm had links with universities or research institutions (5) or with other firms (6), and using two categorical variables that measure the relevance of universities or research centres (7) and other firms (8) as sources of information for the firm's innovation strategy[6].

4.3. Control variables

Our analytical model is completed with a set of firm-level control variables that have

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[6] The scale of these variables is identical to the scale of the other relevance variables. Additionally, the construction of these variables is similar to the previous aggregated relevance variables. Relevance of universities and research centres is measured as $relev\_cyt_{i,t} = \frac{1}{4*n_{cyt}} \sum_{k=1}^{n_{cyt}} info_{i,t,k}$. An analogous formula applies for other firms.

been largely tested in empirical innovation studies.

The size of the firm: The specific effects of size on additionality are ambiguous in the empirical literature, with some studies finding higher additionality in SMEs than in large firms and vice versa (Cunningham et al. 2013). Evidence converges to conclude that the size of the firm positively affects firm innovation propensity while the relationship between innovation intensity and size shows an inverted U shape (Cohen 2010). Therefore, we expect a positive effect of the firm's size on additionality effects. We measured size through the total number of the firm's employees, using a logarithm transformation to deal with non-normal distribution of the variable.

The evidence about the knowledge diffusion effects of *foreign capital* in developing countries is far from conclusive (Marín & Sasidharan 2010; Chudnovsky et al. 2008). These works highlight the mediating role of internal capabilities and human resources in the relationship between FDI and innovative firms' behaviour in developing countries. We expect a positive relationship between foreign capital on behavioural additionality. We measured foreign capital as a dummy variable that indicates whether the firm declares a positive percentage of foreign capital in the total capital.

We use a control dummy variable that measures if the firm belongs to an *economic group*. An economic group can extend the boundaries of the firm and operates as knowledge transmission channel. Moreover, belonging to an economic group can help to overcome financial restrictions of the firm (Huergo & Moreno 2014).

The *age of the firm* is measured as the difference between the year of the survey wave and the year when the firm began business. There is evidence about that age negatively affects innovation intensity in high-tech industries within developed countries (Balasubramanian & Lee 2008) while in low-tech industries, older firms may show more internal assets to conduct innovation activities, particularly embodied innovation activities (Thornhill 2006). Hence, we expect a positive relationship between the age and the effect of public support.

The *activity sector* is a good proxy of the market structure where the firm operates and the technological characteristics of each industry (Cohen 2010). However, the empirical evidence for developing countries shows ambivalent results on the relationship between sector technological intensity and the effects of public support (Cunningham et al. 2013). We use the OECD classification of sectoral technology intensity (OECD 2011). By applying a general classification based on technology intensity in a low-tech economy, we expect a positive correlation between higher technological intensity and innovation investment.

We use two control variables related to the performance of the firm. First, a proxy of *productivity*, measured as gross value added per employee (per capita gross value added) and the export intensity of the firm, measured as the ratio between export and total sales. Recent literature from European countries stresses that both export and productivity are correlated and that they operate softening the financial restriction of the firm (Altomonte et al. 2016). Moreover, export participation has been used as a proxy of competitive learning (Binelli and Maffiolli 2007). Consequently, we expect a positive correlation between performance indicators and innovation investment.

We also include a set of control variables that consider different aspects of innovation behaviour of the firm. First, we use a dummy variable that indicates whether the firm has any STEM (science, technology, engineering and mathematics) professionals as a proxy of the *knowledge base of the firm*. High skill human resources are a key asset of the firm to deal with innovation obstacles and to expand the innovation options that the firm perceives (D' Este et al 2014).

Finally, we consider a dummy control variable that indicates whether the firm had perceived *financial obstacles* to innovation. This typical measure helps to explain the propensity to ask for public support. Moreover, it indicates that the firm is able to recognize obstacles to innovation (D' Este et al. 2012). Therefore, we expect a positive correlation between perceived financial obstacles and innovation investment.

In an extended model to assess behavioural additionality, we also control for the *innovative strategy* of the firm using two dummy variables of external cooperation for innovation that indicate if the firm cooperated with universities or other firms in the previous period. According to the empirical literature (Cunningham et al. 2013), a positive correlation between cooperative activities and innovation investment is expected.

4.4. Econometric models

We will refer to the complementarity or substitutability of private and public funds as the level of additionality. The higher the additionality, private and public funds will be more complementary and vice versa.

Following Hægeland and Møen (2007), our baseline model is:

$$innov_{i,t} = \beta_0 + \beta_1 pub_{i,t} + \boldsymbol{X_{i,t}\varphi} + \mu_i + \gamma_t + \varepsilon_{i,t} \qquad (1)$$

where $innov_{i,t}$ indicates the amount of investment on innovation by firm i in year t, $pub_{i,t}$ indicates the amount of public funds received by firm *i* at year *t*, $X_{i,t}$ is a vector of control variables, μ_i and γ_t are firm and year fixed effects, respectively; and $\varepsilon_{i,t}$ is the error term. β_1 is the coefficient of interest and, depending on the functional form of (1), it quantifies the additionality of public funds (in case the model is linear) or the elasticity (in case the model is log-linear) of the investment in innovation to public support.

The previous specification is not exempt of econometric issues. At best, β_1 correctly estimates the correlation between investment and public support. In other words: although the estimated coefficient is composed by a causal effect and some selection bias, we cannot separately identify the former. Identifying the causal effect would require some exogenous variation in pub, which we do not observe in our data.

Nevertheless, we do minimize –to the best of our ability– potential bias in our estimation of β_1. We do so, mainly, by exploiting the panel structure of our dataset including year and firm fixed effects. In doing so, we control for shocks that affect all firms in a specific year and for time-invariant unobservables of each firm, respectively.

We also control for a set of observable characteristics of firms ($X_{i,t}$), described in section 4.3. In addition, we use robust standard errors allowing for clustering of errors by firms.

What is the expected sign of the remaining bias? If the probability of receiving public funds is correlated with temporary shocks that affect innovation investment, our estimates will be biased. If the government chooses to subsidize firms with higher growth prospects (*picking the winners*), non-supported firms do not constitute an adequate control group and our coefficients will probably overestimate the effect of public support. The reverse could be also true: if the government uses public funds as a way of assisting underperforming firms, our coefficients would be underestimated (Klette et al. 2000). Moreover, in order to explore possible sources of bias, we estimate a linear probability model to recover the determinants of public support.

$$receive\_pub_{i,t} = \boldsymbol{X}^{*}_{\boldsymbol{i,t}}\boldsymbol{\beta} + \mu_i + \gamma_t + \rho_{i,t} \quad (2)$$

where $\mathrm{receive\_pub}_{\mathrm{i,t}}$ is a dummy variable that indicates whether firm *i* received public support in year *t* and $\mathrm{X}^{*}_{\mathrm{i,t}}$ is a vector of determinants that includes the ratio of investment on innovation to sales of firm *i* in *t-3*, a dummy variable that indicates whether firm *i* invested in disembodied innovation in *t-3*, and the control variables used in (1)[7]. We choose a linear probability model in order to control for time-invariant unobservables of each firm, given the panel structure of our dataset.

4.5. Extended model

In an extension of our model, we estimate the following equation

$$behav_{i,t} = \beta_0^* + \beta_1^* dpub_{i,t} + \boldsymbol{X}_{\boldsymbol{i,t}}^* \boldsymbol{\varphi}^* + \mu_i + \gamma_t + u_{i,t} \tag{3}$$

where $behav_{i,t}$ is a variable of the set of 8 indicators selected to carry out the behavioural additionality analysis, detailed in section 4.2. Also, $dpub_{i,t}$ is a dummy variable that indicates whether firm *i* received public support in year *t*. Finally, $\boldsymbol{X}_{\boldsymbol{i,t}}^*$ is the same set of control variables used in (1) except for the financial obstacles variable. We also estimate a variation of (3) where we do not lag the treatment variable.

5. Results

5.1. Descriptive statistics and determinants of public support access

In the period considered, firms increased their innovation investment substantially (Figure 1), more than doubling it between 2003 and 2012. Public support for innovation activities, on the other hand, was also on the rise, especially after 2006. 31.4% of firms in our dataset received public support at least once in the period considered. However, despite this notorious growth, the average amount of money provided by the State

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[7] We include lags for the first wave (2003) since we have the data from the UIS of the triennium 1998-2000. We do not include this survey in our main dataset since it does not collect all the necessary variables in our baseline specification (1).

remained a very small fraction (slightly over 15% at its peak in 2012) of the mean investment level carried out by Uruguayan firms.

[Figure 1 near here]

[Figure 2 near here]

Training and the acquisition of capital goods or ICT were the most frequent innovative activities carried out by the Uruguayan firms, receiving higher amounts of investment (Figure 2).

A basic question that arises from the theoretical framework and from the descriptive analysis is what determines firms' access to public support for innovation? Since our data only offers information about the financial sources of innovation investment, we cannot test a regular selection function for different public programs.

Therefore, we estimate the determinants of access public funding to innovate using similar variables to those used as to control additionality effects. This estimation (Table 2) shows that firms that have obtained public innovation support during the period do not present a particular pattern. The variables that show significant correlation are mainly related to cooperation with other firms and with the innovative experience of the firm, particularly the previous experience in disembodied innovative activities.

[Table 2 near here]

5.2. Are there input additionality effects?

Our results show a significant and positive effect of the amount of public support on innovation investment. The most robust estimations indicate an average additionality of

1.7 (Table 3)[8]. The interpretation of this result is that each *peso* (Uruguayan currency) given by the government to firms increases their private investment by 70 cents, on average. Point estimates diminish significantly after the inclusion of firm fixed effects, suggesting that public funds are given to firms that invest more on innovation activities because of unobservable characteristics. In addition, as it usually happens in empirical studies of innovation at the firm level, some of the control variables lose their significance after including firm fixed effects (Cohen 2010). Although our point estimate suggests that public funds induce higher levels of private investment, we cannot reject the hypothesis of partial substitutability between public and private funds, since our confidence interval ranges from 0.9 to 2.5. We do reject the hypothesis of full crowding-out.

The average elasticity of investment in innovation to public support is 0.12 (Tables 4). Taking into account that the elasticity can be expressed as $\epsilon = \frac{\Delta \text{innov}}{\text{innov}} \Big/ \frac{\Delta \text{pub}}{\text{pub}} = \frac{\Delta \text{innov}}{\Delta \text{pub}} \frac{\text{pub}}{\text{innov}}$, hence additionality can be calculated as $\frac{\Delta \text{innov}}{\Delta \text{pub}} = \frac{\text{innov}}{\text{pub}} \epsilon$. These calculations result in an average additionality of 2, somewhat higher than our linear estimates (but within our confidence interval). Nevertheless, the distribution of this variable is highly skewed to the right, with a median additionality of 0.3 (figure A1 in the Annex). This suggests the presence of highly heterogeneous impacts of public support on firms' innovative investment.

[Tables 3 and 4 near here]

[8] Robustness checks estimated with the full sample of the UIS are presented in table A1 in the Annex.

Therefore, we corroborate our first hypothesis. There are additionality effects of public support on private innovation investment and the effect is higher than unity, indicating that public funds have a crowding-in effect. As a robustness check, we obtain similar estimates when considering the larger sample (Table A1). Table A2 presents the results using a restricted sample that only includes firms that appear two consecutive times in the panel. Our point estimate in the linear model (column A7) diminishes to 1, while log-linear estimates (column A9) remain similar to our baseline specification. Since firms' cooperation levels could be affected by our treatment variable, we estimate the same model but including the lags of our cooperation variables. Results are shown in columns (A8 and A10) and are not fundamentally different from our baseline specification. These latter estimates should be interpreted with care, since the inclusion of lags reduces the number of firms that appear two or more times in our dataset, rendering fixed effects estimates more inefficient.

5.3.Heterogeneity

As was extensively presented above, a recurrent result in the empirical estimation of additionality is the presence of heterogeneous effects related to firm and sector features.

To test for heterogeneities in our estimation, we interact our explicative variable $\mathrm{pub}_{i,t}$ with two dummy variables: one that indicates whether firm *i* had more than 100 employees in year *t* and another one that indicates whether firm *i* belongs to a sector activity classified as high technology according to the OECD classification.

We find that additionality is significantly higher for smaller firms (Table A3 in the Annex). The point estimate of the marginal effect of one additional *peso* in a firm with less than 100 employees is 2.3 (s.d. 0.34), while this diminishes to 1.2 (s.d. 0.35) for larger firms. Furthermore, we find statistical evidence of crowding-in for smaller firms, given that the lower bound of our confidence interval for the marginal effect of small firms is larger than unity. This is theoretically consistent, since small firms are more likely to face financial constrains that reduce their innovation investment levels. We do not find evidence of heterogeneity between firms with different technological levels. Our results do not change when considering the larger sample.

Moreover, to test our second hypothesis we estimate our baseline model for each type of innovation (embodied and disembodied). The results show that public policy only seems to have an impact on investment in embodied innovation activities (Table 5). Robustness checks confirm this result (Table A4 in the Annex).

[Table 5 near here]

We must reject our second hypothesis. Public support does not show any additionality effect on private investment in disembodied innovation activities. For investment in embodied innovation activities, results are very similar to the first estimation of the baseline, except for the log-linear model for embodied innovation that increases to 0.2 (which leads to an estimated average additionality coefficient of 2.8 with median 0.38).

A more intensive additionality relationship between public funding and disembodied innovation was expected because these types of activities are usually riskier and more expensive than those based on the acquisition of goods or technology. However, the results suggest that firms engaged in disembodied activities tend to substitute their own financial resources with public support, while firms that conduct only embodied activities maintain their investment level with own resources. The concluding section elaborates on this result by considering its policy implications.

5.4. Behavioural additionality

Process and organizational innovation

In order to estimate the impact of public support on process and organizational innovation, we regress four dependent variables (namely (1), (2), (3) and (4) reviewed in section 4.2) in year *t* against a dummy variable that indicates whether firm *i* received public funds in that year (Table 6).

[Table 6 near here]

Results suggest that the effect of public support on firms' innovative behaviour varies significantly between each dimension considered. The coefficients are only significant for the relevance of the process innovations and the relevance of training activities (column 15 and 16). Both coefficients are of the expected sign (since 1 represents high relevance and 4 irrelevance in the UIS scale) and their magnitude amounts to 12% of the mean of both the process innovation and the training activities relevance indexes. These results show that public funds in Uruguay do not alter firms' innovation decisions on the extensive margin (i.e. whether they effectively carry out process innovations). However, they do seem to alter decisions on the intensive margin (i.e. improving process innovations that they were already carrying out), since treated firms report higher relevance of their process innovations and training activities with respect to non-treated ones.

We run different robustness checks on our estimates in columns (15) and (16), presented in Table A4 in the Annex. Firstly, we change our dependent variable of relevance of process innovation and we define it as the minimum value declared by firm *i* in all 5 issues described in section 4.2[9]. Results do not change and our estimate is still statistically significant at the 5% level (column A17), although its magnitude is higher in relation to the mean (15%). This is to be expected since our new criterion is less strict than our baseline index. Secondly, we run the regressions using our larger sample as in the previous section. The estimate using the larger sample for the original relevance index (column A18) is somewhat lower (6% of the mean) while the estimate for the training activities (column A19) loses all statistical significance. Therefore, we reinforce our causality claims for the relevance of process innovation, since those estimates are robust to varied model specifications.

Since our dataset allows us to disaggregate our relevance index into specific issues, we run the same regression in column 15 of Table 6 for each of the 5 variables that we use to construct our index. This strategy allows us to assess specific drivers that explain our relevance estimates. According to our estimates, the effect of public support is mainly motivated by an expansion of the productive capacity of firms and a reduction in energy consumption (Table A5 in the Annex). The relevance in all of the remaining aspects of process innovation are statistically insignificant at the usual levels. This finding is consistent with our estimates of input additionality by type of innovation investment, where we only find evidence of additionality in embodied innovation. Our results suggest that the average Uruguayan firm's innovative behaviour can be roughly summarized as the purchase of capital goods in order to increase their production levels without significantly transforming their productive processes or technological capacities.

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[9] For example, if the firm declares that the impact on energy consumption was highly relevant but all other issues were irrelevant, our relevance variable will indicate high relevance. This maintains the categorical nature of the original variable.

Linkages with the NSI

Estimates in table 7 show a similar picture than that of the previous section. Firms that receive public support do not seem to have more interactions with research centres or other firms (columns (17) and (18), respectively). Nevertheless, it remains possible that these firms interact with a greater number of institutions as a result of public support. We are not able to see this in our data, since we only know whether a specific firm had any links with other institutions instead of the specific number of institutions. The interpretation of the statistical insignificance of our coefficients should be, at best, that public support does not motivate firms to develop ties with groups of institutions with whom they were not interacting previously.

[Table 7 near here]

Maybe firms are interacting with the same institutions as before but these interactions are more relevant for their innovative strategies. In order to assess this claim, we change our dependent variables to variables (7) and (8) described in section 4.2., that measure the relevance of the sources of information for innovative activities for each firm. Results for research centres (column (19) of Table 7) and other firms (column (20) of Table 7) indicate that public support does not significantly alter the relevance of the information obtained through other institutions of the NSI. Results do not change when using the larger sample nor when we change our dependent variable with the minimalist criterion described above (Table A7 in the Annex).

Evidence on the impacts of public support on firms' linkages with the NSI is, therefore, less conclusive. This is also consistent with our input additionality results, since the acquisition of information technologies or capital goods is –generally– unlikely to be a cooperative venture. Nevertheless, since our dependent variables exhibit low levels of within-firm variation[10], our identification strategy is severely restricted and could lead to questionable conclusions. Also, changes in the innovative behaviour are likely to take place in the medium-run (Benavente et al. 2007). Since our treatment variable is contemporaneous, our lack of significance could reflect the fact that the impact has a dynamic nature.

5.5. Matching test

In order to test our previous estimates in a non-parametrical way, we carry out a matching strategy to compute the treatment effect following Gonzalez and Pazó (2008). The identifying assumptions are (i) unconfoundedness (potential outcomes are independent of the treatment status, conditional on the observed covariates) and (ii) overlap (for each firm there exists a comparable firm with the opposite treatment status and similar covariates).

We match treated and control firms with a vector of covariates that includes an estimate of the probability of receiving public support, the lagged ratio of innovation investment to sales and year fixed effects. We estimate the former probability with a *probit* model that includes lagged treatment status, the lagged number of employees, a dummy variable that indicates whether the firm carried out disembodied innovation activities in the previous wave, the number of professionals employed in the firm, the lagged ratio of innovation investment to sales and other controls included in our

[10] 68% of firms that ever had links with universities or research centres always declare having them. This figure is 89% for firms that had links with other firms. The standard error decomposition of the aggregated indices also shows low levels of within variation in our relevance scores relative to the overall level.

baseline specification (Table A8 in the Annex). We achieve significant balance in covariates after matching (Table A9 and Figures A2 and A3).

Estimates of the average treatment effect on the treated are shown in Table 8. We match each treated observation with the three nearest neighbours and we use the bias correction proposed by Abadie and Imbens (2006). Our matching results are less supportive of the crowding-in hypothesis, since we find no effects of public support on private innovation investment. When distinguishing between different types of innovation investment, we find no evidence of additionality on embodied innovation and evidence of substitutability of private funds in the case of disembodied innovation. Furthermore, matching estimates obtained after dividing the sample between firms with less than 100 workers and with more than 100 workers lead to the same heterogeneity found in section 5.3. where public funds have a greater effect on smaller firms.

[Table 8 near here]

6. Final remarks and policy implications

The results corroborate the effect of a turning point in the national innovation policy: public support for innovation strongly appears during the re-building and experimentation phase (2006). Chart 1 clearly shows the turning point of the innovation policies in Uruguay. However, this chart also describes the very low amount of public funds obtained by firms since 2006. This may be expressing a disproportionate institutional effort for a very low financial amount. Hence, considering that the data are underestimating the public financial effort in private productive activities, the first conclusion that arises from this paper is the importance to assess the dimension of the public effort devoted to innovation. In this regard, the amount of innovation subsidies for innovation can be a scale barrier. In order to estimate the existence of a minimal threshold amount, further research should include a cost estimation of minimal investment, mainly for disembodied innovation activities.

In addition, our results allow us to conclude that after ten years public subsidies to firms' innovation activities, the innovation dynamic of the Uruguayan economy is still concentrated in a small number of firms, whose innovation activities are based on embodied innovation activities. Actually, observed additionality effects suggest that public funding has reinforced this pattern. It is too early to achieve conclusive evaluation result of the effects of innovation policy in Uruguay. However, this result allows stressing the risk that policies reproduce initial situations.

Is the policy creating new heterogeneities? Is it picking the winners or adding the poors? There is not an indisputable conclusion. First, what is a winner in the Uruguayan context? It is reasonable accept that firm already engaged on innovation based in R&D is a good proxy of 'winner'. In this regard, our results show that firms previously engaged in disembodied innovation activities show more probabilities to access public funding. Moreover, firms that conduct disembodied innovation activities seem to be substituting own resources already allocated to these activities by public resources. This is a picking the winner but inefficient policy. On the contrary, firms that conduct innovation activities based on tangible acquisition use public funds to complement they own resources. These type of innovation activities are crucial to enhance competitiveness but not to create new productive activities and markets.

As was mentioned above, the main challenge of innovation policy everywhere is to change the behaviour of private agents. However, this goal is particularly hard in a economy based on low innovative activities that have experienced a recent period of growth. Why would a rational agent change his behaviour when he is gaining benefits – or, at least when he is not losing money – ?

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Annex

[Table A1 near here]

[Table A2 near here]

[Table A3 near here]

[Table A4 near here]

[Table A5 near here]

[Table A6 near here]

[Figure A1 near here]

Table 1. Structure of the panel.

Survey wave 2003	2006	2009	2012	Frequency	%	Cumulative %
		X	X	97	23.4	23.4
X	X	X	X	65	15.7	39.1
	X	X	X	60	14.5	53.6
	X	X		35	8.5	62.1
X	X	X		31	7.5	69.6
X	X			28	6.8	76.4
X		X	X	24	5.8	82.2
X	X		X	21	5.1	87.3
X			X	20	4.8	92.1
X		X		17	4.1	96.2
	X		X	16	3.8	100

Source: authors based on UIS database

Table 2. Estimation of determinants to access public innovation support (linear probability model).

Innovation investment as a proportion of sales (t-3)	0.0568
	(0.211)
Cooperate with other firms (t-3)	0.160**
	(0.0758)
Cooperate with research institutions (t-3)	-0.0398
	(0.0566)
Invested in disembodied innovation (t-3)	0.106***
	(0.0391)
Per capita gross value added	-2.63e-09
	(9.25e-09)
Number of professionals	0.000465
	(0.000497)
High technology	0.0820
	(0.241)
Service	-0.232***
	(0.0697)
Faced financial obstacles to innovation	0.0111
	(0.0411)
Age	0.00361*
	(0.00194)
Number of employees (in logs)	0.0691
	(0.0898)
Foreign capital	-0.0620
	(0.110)
Belongs to a group	0.0484
	(0.0598)
Year fixed effects	Y
Firm fixed effects	Y
Observations	774
Number of firms	394
R-squared	0.245

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table 3. Input additionality estimations (linear).

	(1)	(2)	(3)
Public support	2.030***	2.057***	1.681***
	(0.272)	(0.271)	(0.395)
Cooperated with other firms	3,320***	5,106***	6,302***
	(1,258)	(1,218)	(2,243)
Cooperated with research institutions	-3,573***	-3,181***	-5,620***
	(1,118)	(1,218)	(1,550)
Export intensity	6,149**	6,056**	11,151
	(2,412)	(2,413)	(8,936)
Number of professionals	-5.597	-5.670	-8.218
	(3.979)	(4.042)	(6.243)
Gross value added per capita	0.000111	0.000121	3.56e-05
	(9.54e-05)	(0.000100)	(5.86e-05)
Number of employees (in logs)	4,534***	4,615***	5,811**
	(943.0)	(964.7)	(2,398)
High technology	844.8	924.3	-3,297
	(1,842)	(1,836)	(3,759)
Service	-4,636**	-4,396**	-351.6
	(1,843)	(1,896)	(1,964)
Age	81.05**	83.14**	11.75
	(38.77)	(39.19)	(55.39)
Foreign capital	283.9	145.3	-9,720*
	(2,191)	(2,200)	(5,279)
Belongs to a group	3,409*	3,542*	-1,075
	(1,852)	(1,862)	(3,078)
Faced financial obstacles to innovation	-2,509**	-2,596**	2,468
	(1,213)	(1,221)	(1,755)
Year fixed effects	N	Y	Y
Firm fixed effects	N	N	Y
Observations	1,094	1,094	1,094
R-squared	0.252	0.254	0.169
Number of firms	414	414	414

Table 4. Input additionality estimations (log-linear).

	(4)	(5)	(6)
Public support	0.176***	0.169***	0.115***
	(0.0169)	(0.0180)	(0.0238)
Cooperated with other firms	0.614***	0.700***	0.740***
	(0.149)	(0.192)	(0.228)
Cooperated with research institutions	-0.297**	-0.235*	-0.441**
	(0.129)	(0.139)	(0.180)
Export intensity	0.730***	0.725***	0.0780
	(0.236)	(0.238)	(0.672)
Number of professionals	-0.000343	-0.000352	-0.00162**
	(0.000294)	(0.000290)	(0.000656)
Gross value added per capita	2.98e-09	1.87e-09	-9.98e-09**
	(1.10e-08)	(1.06e-08)	(4.64e-09)
Number of employees (in logs)	0.548***	0.553***	0.239
	(0.0787)	(0.0790)	(0.254)
High technology	0.312	0.310	0.356
	(0.190)	(0.191)	(0.836)
Service	-0.515***	-0.519***	-0.565
	(0.186)	(0.187)	(0.436)
Age	0.00844***	0.00817**	0.0116
	(0.00324)	(0.00325)	(0.0140)
Foreign capital	-0.0103	-0.00756	-0.576*
	(0.192)	(0.192)	(0.327)
Belongs to a group	0.191	0.190	-0.605**
	(0.177)	(0.177)	(0.273)
Faced financial obstacles to innovation	-0.368***	-0.363**	0.0239
	(0.141)	(0.141)	(0.193)
Year fixed effects	N	Y	Y
Firm fixed effects	N	N	Y
Observations	1,094	1,094	1,094
R-squared	0.178	0.180	0.117
Number of firms	414	414	414

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1
Source: authors based on UIS database

Table 5. Additionality estimations according to type of innovation activity.

	(9) Disembodied linear	(10) Embodied linear	(11) Disembodied log-linear	(12) Embodied log-linear
Public support	-0.00154	1.703***		
	(0.0353)	(0.395)		
Public support (in logs)			-0.0170	0.208***
			(0.0472)	(0.0416)
Cooperates with research institutions	263.0	5,520***	0.183	1.461***
	(225.3)	(2,115)	(0.393)	(0.452)
Cooperates with other firms	215.5	-5,541***	0.159	-0.614**
	(334.6)	(1,480)	(0.298)	(0.306)
Export intensity	-102.2	10,450	1.548**	0.736
	(668.7)	(8,659)	(0.666)	(1.056)
Number of professionals	-0.746	-8.296*	-0.00453***	-0.00168**
	(0.837)	(4.934)	(0.00126)	(0.000750)
Gross value added per capita	-9.45e-07	3.88e-05	-2.74e-08***	-1.83e-09
	(6.79e-06)	(5.34e-05)	(5.07e-09)	(6.32e-09)
Number of employees (in logs)	446.7	5,137**	0.0110	-0.180
	(351.9)	(2,240)	(0.464)	(0.422)
High technology	548.1	-4,489	2.802***	0.108
	(654.8)	(4,537)	(0.952)	(1.936)
Service	-740.8*	495.4	-0.829	-1.382***
	(396.8)	(1,873)	(0.567)	(0.479)
Age	3.971	-2.826	0.00340	0.0115
	(10.87)	(54.65)	(0.0158)	(0.0198)
Foreign capital	309.5	-10,569**	-1.075*	-0.326
	(524.3)	(4,965)	(0.621)	(0.603)
Belongs to a group	671.6	-1,645	-0.0293	-0.732
	(499.5)	(2,994)	(0.456)	(0.481)
Faced financial obstacles to innovation	68.23	2,405	-0.0910	0.261
	(204.3)	(1,751)	(0.288)	(0.338)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	1,094	1,094	1,094	1,094
R-squared	0.024	0.178	0.035	0.082
Number of firms	414	414	414	414

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table 6. Behavioural additionality estimates.

	(13) Process innovation	(14) Organizational innovation	(15) Relevance of process innovation	(16) Relevance of training activities
Received treatment	0.0370	-0.0432	-0.0658***	-0.268**
	(0.0458)	(0.0550)	(0.0226)	(0.131)
Cooperates with other firms	0.0408	0.0497	-0.0120	-0.0891
	(0.0421)	(0.0470)	(0.0174)	(0.101)
Cooperates with research institutions	0.0752	0.0617	-0.0284	-0.182
	(0.0554)	(0.0580)	(0.0217)	(0.137)
Export intensity	0.335**	-0.300**	-0.100**	-0.356
	(0.137)	(0.152)	(0.0462)	(0.311)
Number of professionals	-0.0328	0.105	-0.0379	-0.305**
	(0.0661)	(0.0701)	(0.0253)	(0.149)
Gross value added per capita	-4.53e-10	-5.54e-10	9.33e-10**	2.18e-10
	(7.80e-10)	(1.31e-09)	(3.88e-10)	(2.48e-09)
Number of employees (in logs)	-0.0592	0.0247	0.0230	0.259
	(0.0560)	(0.0707)	(0.0232)	(0.166)
High technology	0.155	0.0993	-0.00884	-0.764
	(0.219)	(0.174)	(0.0698)	(0.875)
Service	-0.418	0.165***	0.0557	0.498
	(0.361)	(0.0433)	(0.0782)	(0.947)
Age	0.00185	-0.000450	0.000453	0.00793
	(0.00240)	(0.00299)	(0.000913)	(0.00539)
Foreign capital	-0.0182	0.0268	0.00739	-0.115
	(0.0951)	(0.104)	(0.0418)	(0.226)
Belongs to a group	-0.0436	0.00318	0.0146	0.163
	(0.0596)	(0.0604)	(0.0233)	(0.124)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	1,094	1,094	1,094	1,094
R-squared	0.038	0.088	0.039	0.051
Number of firms	414	414	414	414
Mean of dependent variable	0.752	0.559	0.727	2.303

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table 7. Linkages with the NSI.

	(17) Had links with universities or research centres	(18) Had links with other firms	(19) Relevance research organizations as sources of information	(20) Relevance of other firms as sources of information
Received treatment	-0.0233	-0.0318	0.00437	-0.00167
	(0.0529)	(0.0371)	(0.0187)	(0.0205)
Cooperates with other firms	-0.115**		-0.0135	-0.0242
	(0.0550)		(0.0203)	(0.0232)
Cooperates with research institutions		-0.0653*	-0.0463***	-0.0340**
		(0.0334)	(0.0134)	(0.0166)
Export intensity	-0.124	0.0178	0.0718*	0.0793*
	(0.163)	(0.0853)	(0.0384)	(0.0447)
Has STEM professionals	0.00564	0.0173	-0.0335	0.0149
	(0.0645)	(0.0471)	(0.0218)	(0.0249)
Gross value added per capita	6.94e-10	-3.48e-10	-1.52e-09***	-2.52e-10
	(1.03e-09)	(6.19e-10)	(2.53e-10)	(3.33e-10)
Number of employees (in logs)	0.0116	-0.123**	0.0310	0.0250
	(0.0704)	(0.0573)	(0.0213)	(0.0264)
High technology	0.0802	0.0681	-0.0510	0.109
	(0.255)	(0.0476)	(0.0741)	(0.119)
Service	0.501***	-0.0195	-0.0195	0.113***
	(0.178)	(0.0335)	(0.0914)	(0.0309)
Age	0.000192	0.000676	-0.00189**	-0.00148**
	(0.00269)	(0.00170)	(0.000947)	(0.000688)
Foreign capital	-0.0510	0.0850	-0.0193	0.0405
	(0.0905)	(0.0690)	(0.0376)	(0.0371)
Belongs to a group	-0.0250	-0.0385	0.00193	0.00120
	(0.0513)	(0.0425)	(0.0213)	(0.0220)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	1,094	1,094	1,094	1,094
R-squared	0.175	0.041	0.046	0.029
Number of firms	414	414	414	414

Clusterized robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table 8. Average treatment effects on the treated (matching estimates)

	GENERAL		EMBODIED		DISEMBODIED	
	Total investment	Private investment	Total investment	Private investment	Total investment	Private investment
ATT	6828.169**	1009.467	5821.704*	3.002199	910.477*	-4908.225***
	(3195.942)	(2708.818)	(3143.18)	(2662.474)	(474.864)	(960.567)
Mean of dependent variable (treated)	12,204	8,262	10,366	6,363	1,277	-2,665
ATT as % of the mean	56.0%	12.2%	56.2%	0.0%	71.3%	184.2%
N Treatment group	269	269	269	269	269	269
N Control group	269	269	269	269	269	269

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: authors based on UIS database

Table A1. Model estimations (extended sample).

	Linear			Log-linear		
	(A1)	(A2)	(A3)	(A4)	(A5)	(A6)
Public support	1.925***	1.936***	1.623***			
	(0.308)	(0.309)	(0.403)			
Public support (in logs)				0.184***	0.172***	0.112***
				(0.0150)	(0.0159)	(0.0198)
Cooperated with other firms	2,917***	5,893***	3,657***	0.503***	0.514***	0.457**
	(983.1)	(2,154)	(1,347)	(0.124)	(0.155)	(0.189)
Cooperated with research institutions	-378.2	603.0	-3,404***	-0.202*	-0.148	-0.292**
	(1,698)	(2,316)	(1,113)	(0.107)	(0.115)	(0.149)
Export intensity	4,721**	4,587**	8,176	0.908***	0.915***	0.294
	(2,100)	(2,122)	(6,067)	(0.200)	(0.201)	(0.572)
Number of professionals	28.24	27.88	-15.16	-0.000195	-0.000213	-0.00126*
	(36.40)	(36.15)	(12.13)	(0.000452)	(0.000441)	(0.000644)
Number of employees (in logs)	4,704***	4,750***	4,323***	0.600***	0.604***	0.295
	(1,237)	(1,243)	(1,495)	(0.0550)	(0.0550)	(0.221)
High technology	-72.66	-69.49	-3,367	0.298**	0.297**	0.139
	(1,421)	(1,416)	(3,651)	(0.147)	(0.147)	(0.756)
Service	-2,195	-1,742	-936.8	-0.284**	-0.302**	-0.391
	(1,466)	(1,574)	(1,036)	(0.143)	(0.143)	(0.314)
Age	105.6**	108.3**	29.72	0.00947***	0.00922***	0.00914
	(48.08)	(47.83)	(45.32)	(0.00277)	(0.00278)	(0.0118)
Foreign capital	-989.5	-1,108	-14,106**	0.0370	0.0363	-0.704**
	(2,209)	(2,232)	(6,563)	(0.165)	(0.165)	(0.305)
Belongs to a group	4,696**	4,826**	4,140	0.246	0.244	-0.289
	(2,363)	(2,384)	(4,235)	(0.151)	(0.151)	(0.229)
Faced financial obstacles to innovation	-1,742	-1,716	3,454**	-0.310***	-0.297***	0.0542
	(1,109)	(1,109)	(1,654)	(0.109)	(0.109)	(0.148)
Year fixed effects	N	Y	Y	N	Y	Y
Firm fixed effects	N	N	Y	N	N	Y
Observations	1,604	1,604	1,604	1,604	1,604	1,604
R-squared	0.151	0.153	0.079	0.236	0.238	0.080
Number of firms	625	625	625	625	625	625

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table A2. Model estimations (extended sample).

	(A7)	(A8)	(A9)	(A10)
Public support	1.055***	1.021***		
	(0.304)	(0.313)		
Public support (in logs)			0.125***	0.115***
			(0.0281)	(0.0290)
Cooperated with other firms	5,803**		0.901***	
	(2,684)		0.846***	
Cooperated with research institutions	-7,285***		(0.285)	
	(2,377)		-0.607**	
Cooperated with research institutions (t-3)		-6,896**	(0.243)	-0.0471
		(3,159)		(0.276)
Cooperated with other firms (t-3)		-509.4		0.0188
		(2,335)		(0.389)
Export intensity	10,696	10,131	-0.583	-0.619
	(9,098)	(9,559)	(0.596)	(0.679)
Number of professionals	31.35*	42.30**	0.00170	0.00277
	(17.20)	(16.40)	(0.00159)	(0.00177)
Gross value added per capita	0.000480	0.000738	9.54e-09	3.01e-08
	(0.00125)	(0.00110)	(5.80e-08)	(5.30e-08)
Number of employees (in logs)	14,453***	15,361***	0.326	0.361
	(5,479)	(5,622)	(0.394)	(0.412)
High technology	-1,834	-2,295	0.397	0.259
	(4,078)	(4,308)	(0.854)	(0.794)
Service	716.9	-5,708	-0.875***	-1.090***
	(4,182)	(4,063)	(0.304)	(0.316)
Age	-65.39	-45.31	0.000620	0.00501
	(69.04)	(70.63)	(0.0114)	(0.0110)
Foreign capital	-6,071	-3,693	-0.523	-0.370
	(8,569)	(8,504)	(0.462)	(0.500)
Belongs to a group	-1,597	-2,502	-0.572*	-0.627*
	(3,831)	(3,995)	(0.331)	(0.344)
Faced financial obstacles to innovation	2,629	1,940	0.161	0.122
	(2,223)	(2,222)	(0.251)	(0.257)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	920	920	920	920
R-squared	0.140	0.122	0.140	0.099
Number of correlativo	539	539	539	539

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

Table A3. Heterogeneous effects estimations (linear).

	(A11)	(A12)
Public support	2.288***	1.630***
	(0.344)	(0.433)
Firm has more than 100 employees	1,199	
	(2,710)	
Public*More than 100 employees	-1.084**	
	(0.483)	
High technology	-1,732	-3,486
	(3,880)	(3,762)
Public*Hi-tech		0.563
		(0.808)
Cooperated with other firms	6,165***	6,227***
	(2,243)	(2,249)
Cooperated with research institutions	-5,693***	-5,671***
	(1,540)	(1,548)
Export intensity	10,764	10,757
	(8,804)	(8,887)
Number of professionals	-6.690	-8.044
	(5.900)	(6.217)
Gross value added per capita	3.08e-05	3.54e-05
	(5.90e-05)	(5.84e-05)
Number of employees (in logs)	5,202**	5,617**
	(2,639)	(2,442)
Service	-666.5	-282.6
	(1,895)	(1,962)
Age	18.08	11.76
	(57.66)	(55.51)
Foreign capital	-9,842*	-9,368*
	(5,229)	(5,243)
Belongs to a group	-542.6	-1,026
	(3,110)	(3,122)
Faced financial obstacles to innovation	2,512	2,514
	(1,752)	(1,750)
Year fixed effects	Y	Y
Firm fixed effects	Y	Y
Observations	1,094	1,094
R-squared	0.180	0.170
Number of firms	414	414

Clusterized robust standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: authors based on UIS database

Table A4. Model estimations by type of innovation.

	(A13) Disembodied linear	(A14) Embodied linear	(A15) Disembodied log-linear	(A16) Embodied log-linear
Public support	-0.0473	1.681***		
	(0.0573)	(0.397)		
Public support (in logs)			-0.0214	0.210***
			(0.0407)	(0.0369)
Cooperated with other firms	140.0	3,123**	-0.0394	1.239***
	(222.3)	(1,281)	(0.294)	(0.353)
Cooperated with research institutions	648.6	-3,769***	0.113	-0.400
	(535.8)	(1,024)	(0.229)	(0.247)
Export intensity	333.8	6,763	0.693	0.419
	(564.9)	(5,738)	(0.615)	(0.873)
Number of professionals	-2.795	-10.00	-0.00404***	-0.00143*
	(2.702)	(6.765)	(0.00139)	(0.000794)
Number of employees (in logs)	-264.2	3,793***	0.534*	0.0839
	(613.8)	(1,375)	(0.308)	(0.304)
High technology	1,512	-4,809	2.103*	-0.0551
	(1,106)	(4,528)	(1.098)	(1.848)
Service	-1,234	-83.91	-0.401	-0.958**
	(1,272)	(1,001)	(0.441)	(0.401)
Age	16.75	8.221	0.00320	0.0134
	(14.94)	(45.07)	(0.0133)	(0.0162)
Foreign capital	237.2	-14,591**	-0.866	-0.394
	(497.0)	(6,328)	(0.581)	(0.583)
Belongs to a group	2,171	994.5	0.108	-0.419
	(1,674)	(2,717)	(0.366)	(0.402)
Faced financial obstacles to innovation	-1,236	3,895*	-0.0232	0.276
	(1,219)	(2,020)	(0.217)	(0.262)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	1,604	1,604	1,604	1,604
R-squared	0.007	0.114	0.020	0.067
Number of firms	625	625	625	625

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table A5. Robustness checks of relevance of process innovations.

	Relevance of process innovation		Relevance of training activities
	(A17) Minimal relevance index	(A18) Larger sample	(A19) Larger sample
Received treatment	-0.307**	-0.0500**	-0.167
	(0.129)	(0.0197)	(0.114)
Observations	1,094	1,604	1,604
R-squared	0.044	0.032	0.035
Number of firms	414	625	625
Mean of dependent variable	2.022	0.734	2.285

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table A6. Estimates of relevance model, disaggregated by type.

	(A23) Productive capacity	(A24) Productive flexibility	(A25) Labour costs	(A26) Input consumption	(A27) Energy consumption
Received treatment	-0.442***	-0.221	-0.185	-0.127	-0.341***
	(0.136)	(0.136)	(0.118)	(0.119)	(0.111)
Year fixed effects	Y	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y	Y
Observations	1,094	1,094	1,094	1,094	1,094
R-squared	0.057	0.039	0.045	0.016	0.025
Number of firms	414	414	414	414	414
Mean of dependent variable	2.358	2.622	3.037	3.240	3.282

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table A7. Robustness checks of linkages with the NSI.

	(A28) Universities	(A29) Other firms	(A30) Universities: relevance	(A31) Universities: minimal relevance	(A32) Other firms: relevance	(A33) Other firms: minimal relevance
Received treatment	-0.00119	-0.0046	-0.00341	-0.0247	0.00328	-0.0650
	(0.0457)	(0.0361)	(0.0164)	(0.0855)	(0.0175)	(0.1000)
Year fixed effects	Y	Y	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y	Y	Y
Observations	1,604	1,604	1,604	1,094	1,604	1,094
R-squared	0.152	0.024	0.047	0.020	0.027	0.037
Number of firms	625	625	625	414	625	414

Clusterized robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Source: authors based on UIS database

Table A8. Probit estimates.

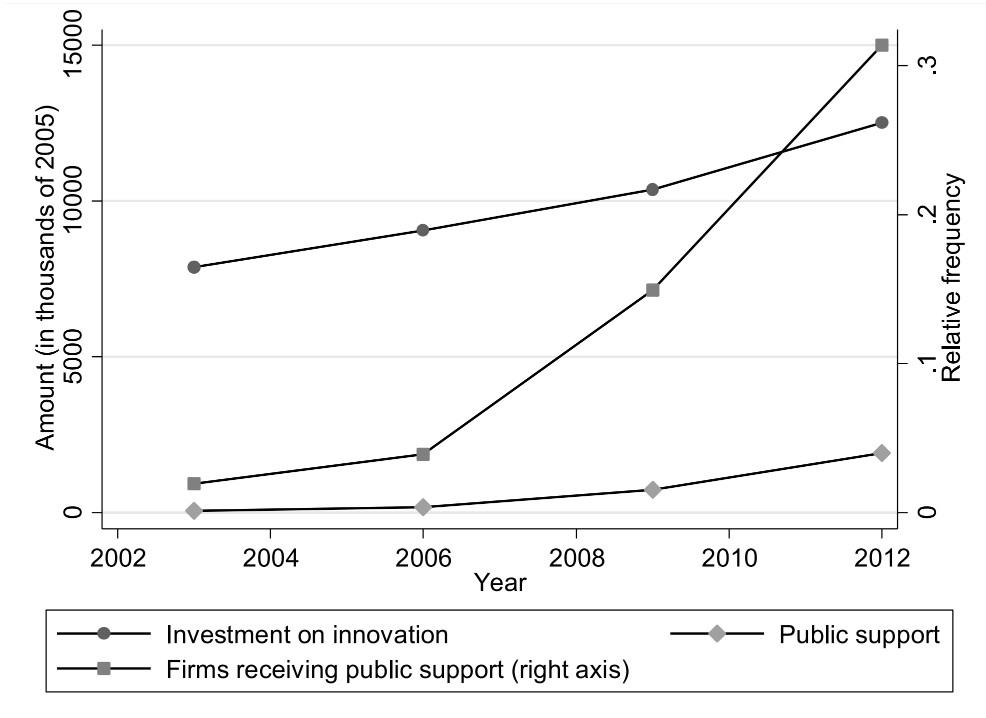
	(A34)
Treatment status (t-3)	0.660***
	(0.164)
Number of employees (t-3)	-5.67e-05
	(0.000126)
Firm carried out disembodied innovation (t-3)	0.411***
	(0.116)
Age	0.00202
	(0.00253)
Number of professionals	0.000722
	(0.000470)
Ratio of innovation investment to sales (t-3)	0.680
	(0.422)
High technology	-0.0555
	(0.138)
Export intensity	0.130
	(0.174)
Foreign capital	-0.229
	(0.144)
Service	-0.660***
	(0.140)
Constant	-2.703***
	(0.275)
Observations	1,107

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

Table A9. Mean comparison of covariates after matching

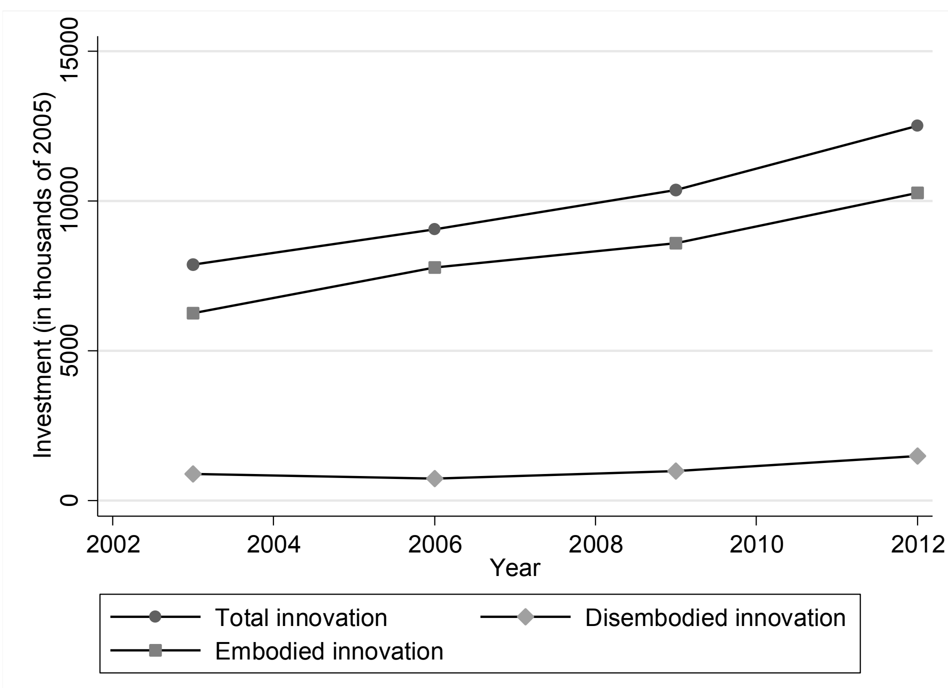
	Treatment	**Control**	**Difference**	**p-value**
Investment on innovation	12,204	12,332	-128	0.969
Cooperated with other firms	0.818	0.843	-0.025	0.433
Cooperated with research institutions	0.361	0.343	0.017	0.675
Export intensity	0.194	0.192	0.002	0.938
Number of professionals	61.729	27.664	34.064	0.197
Gross value added (per capita)	1,665,511	2,198,574	-533,063	0.290
Number of employees (in logs)	257.494	254.310	3.185	0.963
Age	31.610	34.250	-2.640	0.188
Foreign ownership	0.138	0.160	-0.023	0.457
Faced financial obstacles to innovation	0.405	0.306	0.099	0.016
Number of observations	269	269		

Figure 1. Amounts and proportions of innovation and public support.



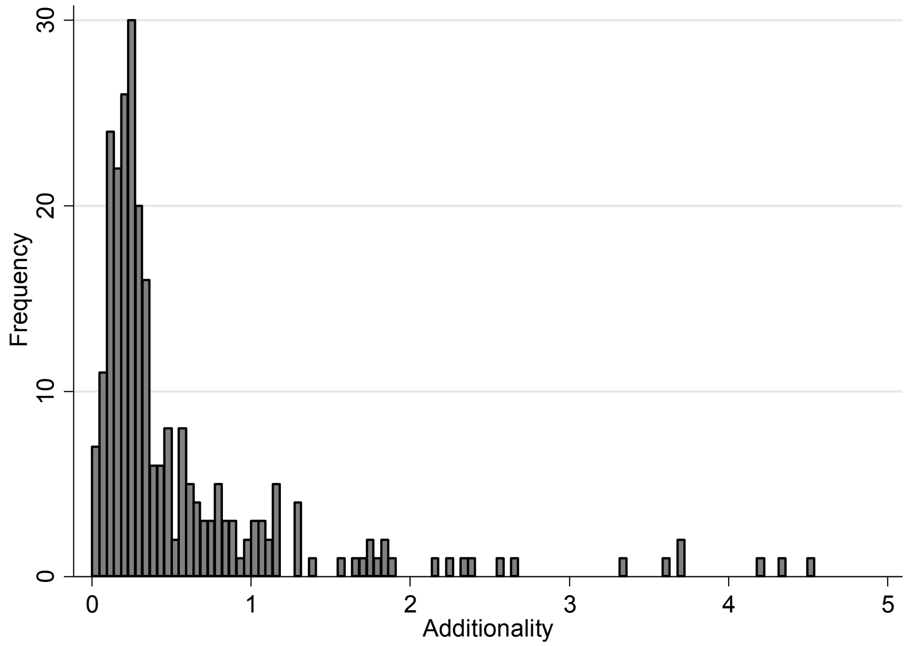
Source: authors based on UIS database

Figure 2. Investment by type of innovation.



Source: authors based on UIS database

Figure A1. Histogram of estimated additionalities (log-linear model).



Source: authors based on UIS database

Figure A2. Densities of treatment probability, pre and post matching

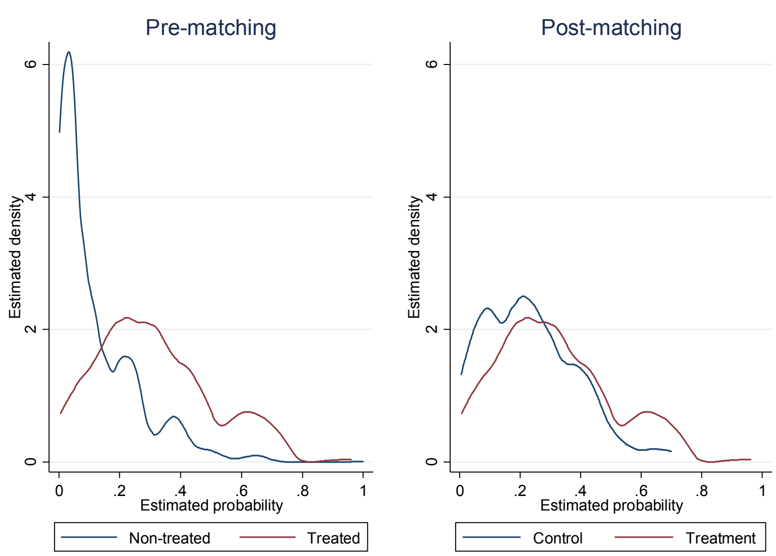


Figure A3. Densities of lagged innovation effort, pre and post matching