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Assessing the effect of public funding on private innovation investment in Uruguay

Felipe Berrutti*
Carlos Bianchi*

Abstract

Despite the recent research efforts and methodological improvements, empirical evidence on the additionality effects of public innovation programs shows heterogeneous results by firm, sector, country and type of innovation. This paper assesses input additionality of public funding on private innovative investment of Uruguayan firms by applying a longitudinal analysis from 2001 to 2012. During this period, there was a dramatic increase of public innovation funds. However, the number of innovative firms remains stable and the amount of public funding for innovation at firm level is still very low. In this context, previous innovation experience appears as the most significant determinant of access to public innovation support. Moreover, we find evidence of a moderate substitution effect between public and private funds. We analyzed heterogeneous effects according to type of innovation, finding significant effects only for innovation based on acquisition of artifacts (embodied). We conclude on the main challenges of the current policy mix in Uruguay, stressing the relevance of further research lines on behavioral additionality to contribute to improve policy results.

Key words: public funding; input additionality, innovation survey, Uruguay

JEL codes: O3, O38, L2; H81

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Análisis de los efectos del financiamiento público sobre la inversión privada en innovación en Uruguay

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Resumen

A pesar de los recientes esfuerzos en investigación y los avances metodológicos, la evidencia empírica sobre los efectos de adicionalidad de los programas públicos de apoyo a la innovación muestra resultados heterogéneos según firmas, sectores, países y tipos de innovación. Este trabajo analiza la adicionalidad del financiamiento público sobre la inversión privada en innovación de las empresas uruguayas aplicando un análisis longitudinal para el período 2001-2012. Durante este lapso de tiempo, los fondos públicos de apoyo a la innovación se incrementaron dramáticamente. Sin embargo, el número de firmas innovadoras permanece estable y los montos de apoyo público por firma continúan siendo muy bajos. En este contexto, contar con experiencia previa en actividades de innovación parece ser el determinante fundamental del acceso al financiamiento público. Además, se encuentra evidencia de un moderado grado de sustitución entre fondos públicos y privados. Analizamos efectos heterogéneos entre tipos de innovación, encontrando efectos significativos solamente para las actividades de innovación basadas en la adquisición de artefactos (incorporada). Concluimos sobre los principales desafíos del conjunto de políticas en Uruguay, enfatizando la importancia de más investigación sobre la adicionalidad comportamental para mejorar los resultados de la política pública.

Palabras clave: financiamiento público, adicionalidad, encuestas de innovación, Uruguay

Códigos JEL: O3, O38, L2; H81

1. Introduction

The study of the effects of public support on the innovation investment behavior of the firms is a classic issue in the economic literature. Several authors have paid attention on this topic using different theoretical backgrounds and empirical strategies (Becker 2015; Zúñiga-Vicente et al. 2014; García-Quevedo 2004; David et al. 2000). By using accurate econometric techniques and panel databases, several methodological biases has progressively been corrected and the results show a moderate prevalence of crowding-in effects (Cunningham et al. 2013).

However, the empirical findings are far from 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 heterogeneous (Zúñiga-Vicente et al. 2014; Cunningham et al. 2013). Hence, further research assessing heterogeneous effects through longitudinal analysis is necessary.

In addition, most of the empirical studies have been focused on public support for R&D, disregarding other innovation inputs. Almost any theoretical point of departure, from the classic market failures argument (Arrow 1962; Nelson 1959) to the recent works that consider the effect of the policy mix as a whole (Neicu et al. 2016; Guerzoni & Raiteri 2015; Köhler et al. 2013), show theoretical arguments that stress the different expected effects of public support according to the type of innovation activity. The distinction between firm endogenous innovation developments based on R&D and technology reception (disembodied innovation) and the acquisition of technological knowledge embodied in artifacts (embodied innovation), makes it possible to distinguish different appropriability conditions, technological risks and the internal capabilities required to conduct the innovation project. All these aspects will affect the effects of public support for innovation at firm level.

The aim of this paper is to analyze the effects of public support on private innovation investment through a longitudinal study (2001-2012) of the Uruguayan firms. The period under analysis includes a recession, crisis and the subsequent recovery process of the Uruguayan economy. Moreover, during this period it is possible to identify three phases of the innovation public policy, from an almost negligible public intervention on private innovation to a dramatic increase in the public support for innovation. It allows us to discuss the general features highlighted in the literature about public support for private innovation investment as well as to discuss the specific situation of the Uruguayan case.

In this regard, the main questions of the paper are: What effects of public innovation support is it possible to identify along the period? Is there evidence of input additionality? Are there heterogeneous effects according to the type of innovation activity carried out by the firms? Is it possible to identify differences before and after the STI policy reform?

To answer these questions we analyze five waves of the Uruguayan Innovation Survey (UIS). We run a linear estimation of additionality using the panel structure of the data set including fixed effects by time and firm. Moreover, as a test of robustness, we estimate the elasticity of the private innovation investment related 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.

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 very low and the total amount of investment seems stable after 2003. Econometric estimations show a moderate degree of substitutability between private and public funds. Moreover, public innovation support programs show effects only in embodied innovation activities. In addition, when we test the determinants to access public support, previous innovative experience in disembodied innovation and cooperative activities appear as the most significant features. The first conclusion that arises from these results is that public support has a moderate additionality effect for innovation activities based on the acquisition of capital goods and information technologies (ICT).

The rest of the paper is organized as follows. Section 2 summarizes the theoretical background about the policy rationale for public support to private innovation activities and the main empirical background on this topic, both in developed countries and in Latin America. Section 3 presents the stylized facts of innovation and innovation policies in Uruguay between 1998 and 2012. Descriptive and econometric results are presented in section 4. Finally, section 5 presents the main conclusions and policy implications of the analysis.

2. Theoretical framework and empirical background

As Chaminade and Edquist (2010: 95) have stressed, innovation policy is a question of the division of labor between public organizations and private (and public) firms. There are different features of this labor division, which in turn involve different practices. One of these features is related to financial issues. Some types of innovation usually require public support while others are normally conducted by firms without explicit innovation support. Nevertheless, in all cases public policies are oriented to influence the behavior of private agents through incentives. These are usually "carrot type" incentives rather than "stick type" ones, hence innovation public policy should attract firms to innovation, looking for a positive sum result (Borrás & Edquist 2013).

This is a basic common sense principle of public policy but it is one of the biggest policy challenges. Why do the firms conduct uncertain activities? Particularly, why do they conduct it when regular activities are profitable?

Public policies oriented to promote private innovative investment try to reduce private uncertainty and costs. They rationale has been founded by the seminal works of Nelson (1959) and Arrow (1962) The basic argument based on the contribution of these authors stresses that, because knowledge and innovation present characteristics of a public good, non-rivalrous and partially excludable, the outcome of innovation investment usually presents imperfect appropriability. Moreover, the effect of private innovation activities on social welfare and economic growth has been proved, stressing the social returns of private investment (Fagerberg et al. 2010). Therefore, the so-called market failures associated with appropriability and externalities would negatively affect the innovation investment propensity of firms. Public intervention is justified by the relevance of public returns, and because in absence of public support, innovation investment tends to be below the socially optimal level (Hall & Lerner 2010).

This type of policies face potential risks related to moral hazard and opportunist behavior of the agents (Takalo 2013). Theoretically, two scenarios are plausible (Crespi et al. 2011). Firms could use public funds in order to finance fixed costs, covering variable costs with their own funds.

In this scenario, public support could complement private investment; increasing total investment in innovation by an amount that exceeds the amount of public funds. The opposite scenario 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 and the innovation budget need not increase mechanically with public support.

There are several specific rationales within the explicit innovation policy mix. Policies are classified according to the mechanism used to deliver financial support (subsidies, tax credit, pre-commercial technological procurement, etc.), to the specific or general target that they follow (mission or diffusion oriented), and to the side of the knowledge production that they try to promote (demand or supply side policies). The delivery mechanism will determine a more direct or indirect policy intervention (Cunningham et al. 2013). The target of policies can be defined by general criterion, such as appropriability failures, for diffusion-oriented policies, while mission oriented policies can be based on a strategic assumption rather than on a general rule (Köhler et al. 2013). Demand side policies are usually associated with mission oriented policies and therefore are usually based on a creation market rational instead that a fitting market failures one.

In this sense, innovation policies have been considered as part of a policy mix more or less consciously designed as an articulated set of policy measures that influence the innovation behavior of the firms and organizations. The innovation policy mix includes both public action explicitly oriented to promote innovation activities and other public actions that implicitly operate as an innovation policy. When a national policy mix is defined as a coherent set of instruments oriented to boost innovation in a systemic way, the final target of innovation policies is not only to increase the amount of innovation investment but also to change the innovation behavior of the firms.

These changes should modify the value attributed to innovation and leverage new investments in internal capabilities (Antonioli et al. 2012; Gök & Edler 2012). To assess the effect of policies in firm behavior beyond the classic additionality test is extremely difficult. The literature of behavioral additionality and evaluation policies offers interesting insight for a further research agenda (Gök & Edler 2012; Hall &Maffioli 2008; Benavente et al. 2007).

However, any type of innovation policy that involves public support for private innovation activities is usually oriented by a basic rationale that states that public support should bring about an increase of global -public and private- effort. Therefore, as Cunningham et al. (2013) propose, based on a broader understanding of the market failure rationale it is possible analyze if - either because moral hazard and opportunistic behavior, or for lack of capabilities - the effects of a public financial support on private investment are neutral, substitute or complementary.

These theoretical propositions have been extensively discussed and empirically tested regarding additional or substitution effects (Becker 2015; Zúñiga-Vicente et al. 2014; García-Quevedo 2004; David et al. 2000). However, as was mentioned before, results are still not conclusive and new empirical studies on specific contexts are necessary.

The more recent empirical literature has improved the additionality estimations showing a moderate convergence to reject the hypothesis of crowding out effects. However, the empirical evidence about the effects of public innovation support for private innovation investment is ambivalent, and especially it shows highly heterogeneous effects (Becker 2015; Guerzoni & Raiteri 2015).

The recent surveys of literature on the topic offer several examples of heterogeneous and ambivalent effects. 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 effect. 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 full 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). In addition, larger firms could face less severe financial restrictions than smaller ones, increasing additionality for minor firms.

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. Also, each specific instrument has shown different effects according type of innovation and firms' performance. Heterogeneity by types of innovation is also particularly likely. On the one hand, given that disembodied innovation is usually considered riskier than embodied innovation (Bontempi 2016); the effect of public funding on the former could be higher than for the latter. On the other hand, the opposite could occur due to embodied innovation being more elastically supplied than disembodied innovation.

Previous works about Latin American countries are less than for OECD countries but there is also a large accumulation on the topic. Several evaluation works analyzed the effects of some national innovation programs that were the basis of national innovation strategies. Binelli and Maffioli (2007) analyzed the Argentinean program FONTAR, finding complementary effects of public support. These authors found a positive elasticity higher than 1 between FONTAR funding and private investment. However, Chudnovsky et al. (2006a) only found evidence of partial additionality when analyzing FONTAR's effects. These author stresses that FONTAR funding increases total innovation investment, but it did not show an elasticity higher than 1. Benavente et al. (2007), using the same methodology than Chudnovsky et al. (2006a), also found evidence of partial additionality when analyzing the Chilean program FONTEC.

Following a similar methodology but using different indicators, Crespi et al. (2011) analyzed the effects of the innovation instrument implemented by the Colombian agency COLCIENCIAS. These authors show that the COLCIENCIAS innovation instruments have had strong effects on productivity and firm performance.

Other studies have analyzed the effect of tax credit for innovation in Latin American countries. Crespi et al. (2016) studied the effects of tax credits for innovation in Argentina by distinguishing between embodied and disembodied innovation activities. These authors found that the elasticity between the capital cost affected by the credit and the innovation investment is higher than 1. However, the additionality effect is only for embodied innovation activities based on capital goods acquisition. This is an unexpected result, since disembodied innovation activities based on R&D usually present more appropriability problems, which can affect the willingness to invest of the firm. These authors link this result with another unexpected one that shows a non-significant effect of tax credit for innovation in high-tech SMEs. Given that one of the target of tax credit for innovation programs is to reduce the investment gap that affects firms that face riskier investments, the result may be showing an implementation or design failure that hamper policy objectives.

Kannebley and De Prince (2015) show similar result 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 other based on external acquisition. Hence, the capabilities of the firm can operate as an internal barrier non related to capital restriction or appropriability problems.

3. Innovation and public policies in Uruguay

The Uruguayan economy has been traditionally based on the exploitation of natural resources and low-tech industries and services. This productive and commercial specialization, articulated with advanced industrial relations and the spread of public services, contributed to the relative high welfare performance of the country during the first half of the XX century. However, the economic performance has showed chronic problems of stability of growth rates and vulnerability from external shocks (Bértola et al. 2005).

Based on an extensive empirical evidence it is possible to describe some stylized facts of the Uruguayan firms innovation behavior between 1998 and 2012. 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 of innovation activity is around 30% (ANII 2014; Bianchi 2007). Within the innovative firms, the most frequents are embodied activities based on the acquisition of capital goods. The large and old firms show more propensity to innovate than young and SMEs. However, the Uruguayan economy shows high heterogeneity between and within sectors of activity. In addition, there are chronic lacks of high skilled human resources (Bianchi et al. 2015; Cassoni & Ramada 2013; Cassoni 2012; Bittencourt 2012a and 2012b). Public investment on innovation activities has multiplied by 6 since 2008, but both the firms and the government face scale restrictions to innovation investment. The amount of the national effort on innovation and the amount of the regular innovation projects are lower than the average project amount in the region (Aboal et al. 2014). Moreover, there are barriers to mobilize knowledge demands from productive activities to research institutions (Arocena & Sutz 2010).

However, it does not mean that Uruguayan firms do not conduct innovation activities. Actually, they do so and obtain technological and economic results. Several works show the incidence of innovation in the creation of highly skilled workplaces (Zuniga & Crespi 2013; & Zuniga 2012; Aboal et al. 2011), the growth of productivity as well as the relevance of human resource in the participation in collaborative innovation projects (Bianchi et al. 2011).

This brief description covers all the period from 1998 to 2012. However, during these years the Uruguayan innovation system experienced a critical juncture. Since the beginning of the XXI century, after a severe crisis of 2002, a consensus around the relevance of innovation as a tool for sustainable growth and development has grown. Beyond rhetorical contents, this consensus has been followed by policy actions. Since 2007 new instruments and programs have been implemented under a new institutional framework and supported through an increase of the public investment in the field (Bianchi et al. 2014). The most visible institutional changes were the creation of a Ministry Cabinet in charge of innovation policies and the creation of a new agency devoted to implement instruments and programs. Meanwhile there were changes in the implicit innovation policies, such as a substantive transformation of the investment promotion regime and the development of new industrial policies (Bianchi et al. 2014; Aboal et al. 2014).

It is possible to identify three sub-periods of innovation policies in Uruguay from 2000 to 2012 (Bianchi et al. 2016). First, a period that can be define as ad hoc innovation policies (1998-2006). Before the policy reform, there were a little number of innovation programs, mainly concentrated around the first Technological Development Program, supported by the IADB. After that from 2006 to 2012, there was a re-building and experimentation process, were old and new programs were implemented. During this phase old and new programs were tested, some of them were improved and re-launched while others were discontinued. 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. They are mainly located under the responsibility of the National Agency of Research and Innovation (ANII by its Spanish acronym) but there are also a number of program delivered by several other agencies, institutes and Ministries.

One of the main challenges of this recent reform of the innovation public policies is to influence the private innovative behavior through different instruments. The policy rationale of the public intervention is based on the assumption that public support may incentive private actors to invest own resources and, always under uncertainty, achieve a subsequent virtuous cycle of innovation investment and results. It is worth taking into account that it does not make any sense to expect a radical transformation of the innovative behavior of Uruguayan firms due to the fact that available public instruments are very recent. However, it is necessary to conduct deeper estimations of the incidence of public support in private innovation both in quantitative sense –i.e. number or share of innovative firms- and qualitative incidence –i.e. increment of private investment and type of activity conducted-.

There are a number of studies that evaluate the effect and impact of innovation policies since 2006. The report published by ANII (2014) analyzes the impact of innovation programs conducted by this agency by estimating additionality effects of public funding in private innovation investment. In addition, it estimates the impact of ANII programs on the innovative and economic performance of the firms. The authors applied quasi-experimental econometric techniques to analyze survey and ANII administrative data. They show that the firms that received public support have invested more in innovation activities than the innovative firms that did not receive public support. Moreover, they offer significant evidence of positive effects of innovation policies in economic performance of the firms.

Another work that uses similar econometric techniques to analyze innovation survey data in order to estimate the impact of public innovation policies is Aboal and Garda (2015). These authors find additionality effects of public support on private innovation investments. However, they neither observe new effects on early innovator nor productivity gains associated to public innovation support. Lasarga et al. (2015), using more recent data, find similar results than Aboal and Garda (2015).

4. Methodology

The aim of this paper is to assess the effects of public funding on private innovation investment. Particularly the specific objectives are: i) to estimate input additionality effects of public funding on private investment; ii) to estimate heterogeneous effects of public support on private innovation investment according to the type of innovation activity conducted by the firms, and, iii) to identify changes before and after of the recent innovation policy reform.

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, there is expected a crowding-in effect of public funding on private innovation investment. However, there is not expected a significant effect of additionality on the overall 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, it is expected 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.

4.1. Data

To test these hypotheses we use a unique database, which contains information from multiple datasets. The main sources are the five Uruguayan Innovation Surveys (UIS), triennial surveys that cover the period 1998–2012. 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 5 employees or more[1]. We join the five surveys in order to obtain an unbalanced panel dataset using unique firm identifiers provided by the ANII.

Previous works have used innovation survey data to assess additionality of public innovation policies. Many of them apply quasi-experimental econometric techniques (Freitas et al. 2017; Marino et al. 2016) while other use elasticity estimation functions (Klette et al. 2000). As we will elaborated on this section, innovation survey data should be used carefully to assess policy effects. Firstly, it is only possible to distinguished different programs after the fourth wave (2006-2009). Therefore, we can only work with information about 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[2]. We are able to merge both datasets using common identifiers provided by the National Institute of Statistics (INE by its Spanish acronym).

Since we require lagged information, we keep only those observations belonging to an innovative firm that appears at least two consecutive times. After constructing the lagged variables[3], some further cleaning and removing outliers, the final working dataset contains 953 observations belonging to 553 firms. The number of observations slightly increases when we include firms surveyed in the UIS but not included in the ASEA: 1,143 observations from 660 firms.

[1] The UIS is collected through stratified random sampling. Large firms (namely, those with more than 50 employees or with an annual turnover larger than an amount that varies between 1 and 4 million US dollars) are forcefully included in the sample.
[2] Pre-2009 surveys are representative of firms with 5 employees or more.
[3] Note that this implies losing at least one observation of each firm.

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.

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; due to the fact that smaller firms are partially excluded from our analysis[4]. Furthermore, due to this issue being common in related literature; we can provide an international comparison of the obtained estimates (Raymond et al. 2010; Mairesse & Mohen 2010).

As seen in Table 1, approximately 44% of the firms are present more than once in our panel, and 18% of those are present in more than half the time period considered (2003-2012).

Table 1. Structure of the panel

Survey wave				**Frequency**	**%**	**Cumulative %**
2003	2006	2009	2012			
			X	145	26.22	26.22
X				90	16.27	42.50
		X	X	84	15.19	57.69
		X		59	10.67	68.35
X	X	X	X	58	10.49	78.84
X	X			30	5.42	84.27
X	X	X		22	3.98	88.25
	X			16	2.89	91.14
X			X	16	2.89	94.03
Other patterns				33	5.97	100.00

Source: authors based on UIS database

The average firm in our dataset has 269 employees and an annual turnover of 481 million Uruguayan pesos of 2005 (approximately 19 million American dollars of 2005). 77.7% 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 five UIS. In this latter dataset firms on average employ 180 workers, only 55% of them have more than 50 employees and their average annual turnover is 16% smaller than in our working dataset.

[4] This is due to the fact that the questionnaire is designed to only report information on innovation related questions for innovative firms.

Also, the technological intensity of firms[5] is higher in our sample (22% are in high technology sectors) than in the pool of innovative firms (12%).

4.2. Dependent and explicative variables

The main variables, used as dependent and explicative in our analysis, are: i) the amount of money invested on innovation activities, ii) an indicator if the firm received public financial support for innovation and iii) the amount of public money received by the firm for innovation activities. Since the questionnaire used in each UIS has been slightly altered between each wave, some recoding process was made in order to obtain uniform variables for the entire period. In this subsection, we briefly summarize the method for constructing dependent and explicative variables.

The main difference in the reporting of total investment on all innovation activities occurs in 2012. Previously, firms reported the amount of investment only in the final year of the three year period of each UIS. In 2012, firms were asked to report investment on each of the three years individually. Comparing the wave 2012 with the wave 2009, we find substantial differences when considering only the annual investment that are reduced when we consider the total amount in the triennium[6]. We therefore use the sum of the investment carried out in 2010, 2011 and 2012 as the amount of investment in 2012.

Variables related to public support for innovation require further coding. 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.

Finally, in order to estimate heterogeneous effects of policies according different type of innovation we transform the first dependent variable. 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).

4.3. Control variables

Our analytical model is completed with a set of firm-level control variables that have 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). On other hand, previous studies about

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

[6] Average investment on innovation in 2009 is 19,632 (in thousands). Considering only the annual amount in 2012, this falls to 6,940 (the value is lower than the average for 2003); whereas we obtain 18,565 when adding all three years.

innovation in Latin America stressed that the relative small size of the local firms can affect the access to the minimal financial and human resources needed to conduct disembodied innovation activities (Crespi & Tascir 2012; Chudnovsky et al. 2006b).

Therefore, considering the empirical background about the region and the country, 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.

Foreign capital into the firm has showed a positive relationship with innovation propensity in developed economies as well as in countries integrated into global investment fluxes (Stiebale & Reize 2011; Roper & Hewitt-Dundas 2008). However, the evidence about the knowledge diffusion effect of foreign capital on 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. Taking into account this last argument, we expect a positive relationship between foreign capital on additionality, when controlled by internal firm capabilities. Regarding the dataset contents, we measured foreign capital as a dummy variable that indicates whether the firm declares a positive percentage of foreign capital in the total capital.

Based on similar arguments, we use a control dummy variable that measures if the firm belongs to an *economic group*. It indicates if the firm is engaged in strategic relationship among the group’s firms. 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. The relationship between the age and the innovation behaviour of the firm is controversial, with both theoretical and empirical arguments stressing differences according to industry and context. However, there is basic consensus 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). Moreover, Paunov (2012) analyzing data from Latin American countries, which includes Uruguay, found a positive relationship between age of the firm and the probability of crowding-in effects of public support. Hence, we expect a positive relationship between the age and the effect of public support.

The sector of activity is another observable characteristic of the firm that we use to control the analysis of public support effects. The relevance of the activity sector as indicator of market structure and technological characteristics of the firm has been largely emphasized (Cohen 2010). However, the empirical evidence for developing middle-income 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). This classification has the usual shortcoming of any taxonomy applied *ex post* in another context. Hence, the results should be considered carefully. However, the OECD classification is based on an empirical exercise and, since it has built using four digit ISIC codes, the average technological intensity of each type is reliable. 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). In addition, recent works about export and innovation performance of Uruguayan firms have shown a positive and bi directional effect between export and innovative propensity (Peluffo & Silva 2016; Resnichenko 2017). Consequently, we expect a positive correlation between performance indicators and innovation investment.

We also include a set of control variables that consider different aspect of innovation behavior of the firm. First, we use the number of professionals employed by the firm 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; Østergaard et al. 2011). Moreover, even though the presence of highly skilled workers is unusual in Uruguayan firms, there is significant evidence that the presence of at least one professional in the firm's workforce positively affects the innovation propensity of the firm (Bianchi et al. 2015) and the probability that the firm will engage in collaborative innovation activities (Bianchi et al. 2011).

As a proxy of the *innovative strategy* of the firm we use two dummy variables of external cooperation for innovation that indicate if the firm cooperated with universities or other firms. According to the empirical literature (Cunningham et al. 2013), a positive correlation between cooperative activities and innovation investment is expected.

Finally we consider a dummy control variable that indicates whether the firm had perceived financial obstacles to innovation. This is a typical measure that 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.

4.4. Econometric models

The aim of this research is to shed light on the additionality effects of public support on innovation activities at the firm level and to test for heterogeneous effects of public support according to the type of innovation activities.

The first effect we will assess is straightforward and of clear policy relevance: does giving public funds to firms increase their levels of innovative investment? This question ultimately seeks to answer whether private and public funds are complements or substitutes. 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 $\mathrm{innov}_{i,t}$ indicates the amount of investment on innovation by firm i in year t, $\mathrm{pub}_{i,t}$ 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, exploiting the panel structure of our dataset by including year and firm fixed effects. These fixed effects 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 rich set of observable characteristics of firms ($X_{i,t}$), described in section 4.3, applying lagged and contemporaneous measurements. 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). Based on the empirical background, we think that, for Uruguay, the first case is more plausible. Therefore, "true" coefficients should be somewhat lower than our estimates. Moreover, in order to explore possible sources of bias, we estimate a linear probability model to recover the determinants of public support.

$$receive\_pub_{i,t} = \boldsymbol{X^*_{i,t}\beta} + \mu_i + \gamma_t + \varepsilon_{i,t} \qquad [2]$$

where $receive\_pub_{i,t}$ is a dummy variable that indicates whether firm *i* received public support in year *t* and $X^*_{i,t}$ 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]. We choose a linear probability model in order to control for time-invariant unobservables of each firm, given the panel structure of our dataset.

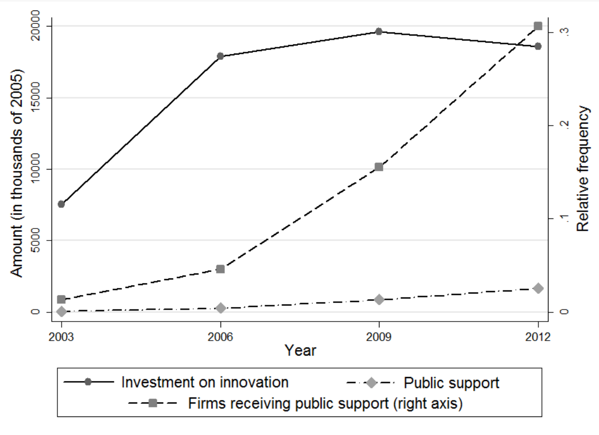
5. Results

Descriptive and econometric results show that there are moderated effects of public support for innovation in the investment behavior of the firms. Notwithstanding, as it was mentioned before, because of data limitations and the small scale of the innovation programs these results must be analyzed carefully.

5.1. Descriptive statistics and determinants of public support access

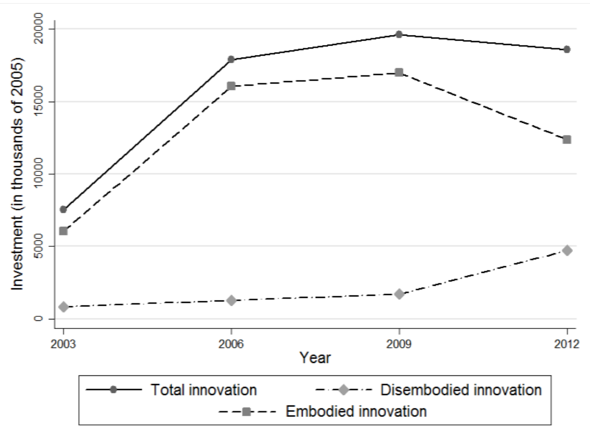
In the period considered firms increased their innovation investment substantially (Chart 1), more than doubling it between 2003 and 2012. Public support for innovation activities, on the other hand, was also on the rise, especially after 2006. The number of firms that receive public funding increased dramatically. However, despite this notorious growth, the average amount of money provided by the state remained a very small fraction (roughly 9% at its peak in 2012) of the mean investment level carried out by Uruguayan firms.

Chart 1. Amounts and proportions of innovation and public support



Source: authors based on UIS database

Chart 2. Investment by type of innovation



Source: authors based on UIS database

Training and the acquisition of capital goods or ICT were the most frequent innovative activities carried out by the Uruguayan firms, as table 2 shows. In addition to being less frequent than embodied innovation activities, disembodied innovation also receives less amounts of investment (see Chart 2). Although, on average, firms invest 6.8% of their sales on innovation activities; only 1.4% is invested in disembodied innovations.

Table 2. Proportion of innovative firms, by type of innovation activity

Wave	Internal R&D	External R&D	Capital goods	ICT	Tech. transfer	Eng. & indust design	Organizational	Training
2003	54.0%	16.8%	58.0%	59.3%	25.2%	40.7%	39.8%	57.1%
2006	45.4%	14.5%	72.4%	61.2%	23.7%	30.3%	27.6%	74.3%
2009	44.8%	12.7%	66.7%	43.7%	23.8%	21.4%	25.8%	74.2%
2012	39.3%	14.2%	64.7%	50.5%	16.7%	21.7%	18.9%	47.7%
Total	**45.2%**	**14.5%**	**64.8%**	**52.5%**	**21.7%**	**27.5%**	**27.1%**	**61.2%**

Source: authors based on UIS database

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 3[7]) shows that there is not a clear pattern of the firms that have accessed to public innovation support during the considered period. The variables that show significant correlation are mainly related to the innovative experiences of the firm, particularly the previous experiences in disembodied innovative activities. However, we include a measurement of innovative intensity of the firm - lagged ratio between innovation investment and total sales - that does not show significant correlation with the access to public innovation funding. In the same vein, others variables related to innovation experiences of the firm -e.g. cooperation with research institution- do not show significant correlation. In sum, evidence is not conclusive, but in the light of some previous work about innovation in traditional industries (Radicic et al. 2014) it is not possible to discard the hypothesis that the relevance of experience in embodied innovation activities indicates evidence that the policy is 'picking the winners'.

[7] Robustness checks are presented in table A1.

Table 3. Estimation of determinants to access public innovation support
(linear probability model)

	(0)
Innovation investment as a proportion of sales (t-3)	-0.0757
	(0.124)
Cooperate with other firms (t-3)	0.146**
	(0.0731)
Cooperate with research institutions (t-3)	-0.0315
	(0.0552)
Invested in disembodied innovation (t-3)	0.103***
	(0.0375)
Per capita gross value added	-1.55e-09
	(9.21e-09)
Number of professionals	0.000415
	(0.000478)
High technology	0.0642
	(0.243)
Service	-0.223***
	(0.0674)
Faced financial obstacles to innovation	0.00890
	(0.0411)
Age	0.00256*
	(0.00150)
Number of employees (in logs)	0.0616
	(0.0860)
Foreign capital	-0.0499
	(0.107)
Belongs to a group	0.0726
	(0.0548)
Constant	-0.443
	(0.405)
Year fixed effects	Y
Firm fixed effects	Y
Observations	952
Number of firms	553
R-squared	0.237

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

Source: authors based on UIS database

It is worth mentioning that the negative and significant coefficient that shows the variable of services sectors is explained because this sector only registers three measures.

5.2. Are there additionality effects?

Our results show a significant and positive effect of the amount of public support on innovation investment. However, this is a moderate effect that does not imply a crowding-in effect. Our estimations indicate an average additionality of 0.780 (Table 4). This suggests a moderate degree of substitutability between private and public funds[8].

The average elasticity of investment in innovation to public support is 0.109 (Tables 5). 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

[8] Robustness checks estimated with the full sample of the UIS are presented in table A2 in the Annex

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 2.2. Nevertheless, the distribution of this variable is highly skewed to the right, with a median additionality of 0.32 (see figure A1 in the Annex).

Therefore, our first hypothesis is partially rejected. There are additionality effects of public support on private innovation investment ($\beta > 0$), but the coefficient is lower than 1, indicating that there is not a crowding in effect.

As usually happens in empirical studies of innovation at firm level, when fixed effects by firm are applied, most of the control variables lose their significance (Cohen 2010). The most robust estimates suggest that public support has a moderate substitution effect on private innovation investment when observable and unobservable characteristic of the firm are controlled for.

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 $\text{pub}_{i,t}$ with two dummy variables: one that indicates whether firm i had more than 100 employees in year t and another one that indicated whether firm i belongs to a sector activity classified as high technology according to the OECD classification.

We find insignificant effects on the interaction terms but the sign of the coefficients of the interaction suggest that additionality is lower for larger firms and higher for firms in high technology sectors (Table A3 in the Annex).

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 6). Robustness checks confirmed this result (Table A4 in the Annex).

Firstly, 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. They show a moderate effect of substitution, expressed by a positive but very low elasticity coefficient.

Secondly, the available data does not offer clear insight to understand this result. 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 artifacts. However, the results suggest that firms engaged in disembodied activities tend to substitute own financial resource for public support, while firms that conducted only embodied activities maintain the investment level with own resources. The next section elaborates on this result by considering its policy implications.

Table 4. Additionality estimations (linear)

	(1)	(2)	(3)
Public support	1.942***	1.954***	0.780*
	(0.407)	(0.406)	(0.405)
Cooperated with research institutions (t-3)	-4,208	-3,884	-10,132**
	(3,422)	(3,904)	(4,823)
Cooperated with other firms (t-3)	3,750	4,815	3,996
	(4,358)	(5,194)	(4,969)
Export intensity	13,976**	14,021**	8,024
	(6,456)	(6,507)	(13,001)
Number of professionals	19.84	20.28	85.77
	(27.38)	(27.37)	(54.28)
Gross value added per capita	0.000187	0.000192	-0.000365
	(0.000193)	(0.000199)	(0.00144)
Number of employees (in logs)	9,192***	8,977***	29,024**
	(2,226)	(2,232)	(12,246)
High technology	1,685	1,580	-1,070
	(2,314)	(2,310)	(6,679)
Service	-3,384	-3,067	-816.7
	(5,060)	(5,465)	(5,194)
Age	-7.779	-7.289	77.20
	(89.02)	(87.29)	(100.2)
Foreign capital	-13,622**	-13,692**	-9,635
	(6,697)	(6,735)	(8,745)
Belongs to a group	16,819**	16,682**	131.9
	(8,478)	(8,474)	(10,945)
Faced financial obstacles to innovation	-5,528*	-5,491	9,940
	(3,317)	(3,396)	(8,013)
Constant	-33,377***	-33,714***	-133,115**
	(10,153)	(10,563)	(59,026)
Year fixed effects	N	Y	Y
Firm fixed effects	N	N	Y
Observations	953	953	953
R-squared	0.102	0.102	0.062
Number of firms	553	553	553

Table 5. Additionality estimations (log-linear)

	(4)	(5)	(6)
Public support	0.167***	0.154***	0.109***
	(0.0203)	(0.0209)	(0.0290)
Cooperated with research institutions (t-3)	-0.0755	-0.159	-0.0223
	(0.161)	(0.166)	(0.267)
Cooperated with other firms (t-3)	0.479***	0.215	0.0889
	(0.165)	(0.262)	(0.379)
Export intensity	0.675***	0.694***	-0.703
	(0.235)	(0.235)	(0.699)
Number of professionals	-0.000323	-0.000304	0.00299*
	(0.000399)	(0.000398)	(0.00176)
Gross value added per capita	2.21e-09	7.51e-10	1.75e-08
	(1.07e-08)	(1.01e-08)	(5.37e-08)
Number of employees (in logs)	0.642***	0.631***	0.654
	(0.0765)	(0.0763)	(0.469)
High technology	0.194	0.185	0.307
	(0.180)	(0.181)	(0.827)
Service	-0.643***	-0.715***	-0.996***
	(0.206)	(0.209)	(0.316)
Age	0.00674*	0.00674*	0.00516
	(0.00347)	(0.00344)	(0.00760)
Foreign capital	0.0636	0.0643	-0.420
	(0.205)	(0.205)	(0.494)
Belongs to a group	0.399**	0.388**	-0.742*
	(0.196)	(0.197)	(0.387)
Faced financial obstacles to innovation	-0.384**	-0.364**	0.195
	(0.149)	(0.149)	(0.262)
Constant	3.898***	3.719***	4.343**
	(0.353)	(0.365)	(2.200)
Year fixed effects	N	Y	Y
Firm fixed effects	N	N	Y
Observations	953	953	953
R-squared	0.219	0.226	0.105
Number of firms	553	553	553

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

Source: authors based on UIS database

Table 6. Additionality estimations according to type of innovation activity

	(9) Disembodied linear	(10) Embodied linear	(11) Disembodied log-linear	(12) Embodied log-linear
Public support	-0.00664	0.807**		
	(0.0668)	(0.410)		
Public support (in logs)			-0.0189	0.156***
			(0.0623)	(0.0542)
Cooperates with research institutions (t-3)	125.2	-10,027**	0.333	0.183
	(1,005)	(4,695)	(0.441)	(0.508)
Cooperates with other firms (t-3)	2,350	992.9	0.0718	0.648
	(1,599)	(4,647)	(0.639)	(0.761)
Export intensity	2,030	3,911	2.694**	-0.510
	(1,688)	(12,897)	(1.209)	(1.468)
Number of professionals	1.945	78.40	-0.00810***	0.00354*
	(3.508)	(53.92)	(0.00219)	(0.00208)
Gross value added per capita	-0.000101	-0.000362	-6.40e-08	-1.28e-07
	(0.000157)	(0.00149)	(6.37e-08)	(1.79e-07)
Number of employees (in logs)	1,509	27,175**	-0.829	0.861
	(1,057)	(11,979)	(0.747)	(0.833)
High technology	1,529	-3,566	2.165*	0.150
	(1,117)	(6,434)	(1.283)	(2.021)
Service	-618.2	-49.15	-1.023*	-0.536
	(1,274)	(4,929)	(0.597)	(0.707)
Age	82.15	-13.27	0.00263	0.00731
	(65.12)	(63.33)	(0.0218)	(0.0187)
Foreign capital	1,447	-12,292	-0.416	-0.252
	(1,085)	(8,061)	(0.935)	(0.956)
Belongs to a group	-322.9	711.2	0.174	-0.841
	(1,595)	(10,808)	(0.581)	(0.639)
Faced financial obstacles to innovation	151.3	9,759	0.318	0.610
	(339.0)	(8,032)	(0.407)	(0.498)
Constant	-8,884	-122,111**	6.823*	1.469
	(5,998)	(57,684)	(3.504)	(3.855)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	953	953	953	953
R-squared	0.063	0.055	0.041	0.075
Number of firms	553	553	553	553

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

Source: authors based on UIS database

6. Final remarks and policy implications

The obtained results do not allow conclusive final remarks. Considering the difficulty of the topic itself and the quality of data used to analyze a barely incipient process, caution is highly recommended.

However, it is possible to discuss the result by considering its policy implication and new research questions to improve our comprehension of the effects of public policies in Uruguay.

The results corroborate the effect of a critical juncture: 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, it is necessary to check the amount of innovation public support delivered to private firms by considering other data sources. As complement of UIS data, information about the amounts of public support according to instrument is necessary.

Is the current policy picking the winners? There is not an indisputable conclusion. Our results suggest 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. On the contrary, firms that conduct less sophisticated innovation activities seems to use public funds to complement they own resources.

A pick winner oriented policy is not necessary a bad policy. This kind of policies should be considered within a broad policy mix. In his particular case, a picking the winner policy can be one of determinants of the low and stable proportion of innovative firms. This type of policies are oriented to promote the most innovative firms rather than expand the critical mass of firm that conduct innovation activities.

The whole situation seems to reflect that Uruguay is investing little and wrong. Once again, it is not possible to offer clear conclusions, but our results highlight the importance of new research aiming to more robust evidence.

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

Obviously, we do not know the answer to this question. To deal with these fundamental questions, recent literature suggest to analyze the effects of the policy mix as whole, by considering different types of additionality (Neicu et al. 2016; Guerzoni & Raiteri 2015). It involves estimating behavioral additionality (Gök & Edler 2012). It is initially feasible through the available data, using indicators of organizational change and management (Benavente et al 2007; Hall & Maffiolli 2008). A second step requires accessing to administrative register of the innovation programs.

A possible strategy to analyze the effect of the policy mix considering the specific incidence of different type of instruments is to assess the heterogeneous effects of heterogeneous programs -i.e. classic subsidies for projects that show innovative merits and industrial and technological extensionism-. This is a suitable way to access the programs according to its specific targets. However, it does not imply to disregard the importance to assess the real public effort to promote innovation as a whole.

7. References

Aboal, D. Garda, P. (2015). "¿La financiación pública estimula la innovación y la productividad? Una evaluación de impacto". *Revista CEPAL*, 115, 45-70.

Aboal, D. Angelelli, P . Crespi, G. Lopez, A. Vairo, M. (2014). "Innovación en Uruguay". IADB. Research Report. Montevideo.

Aboal, D. Garda, P. Lanzilotta, B. Perera, M. (2011). "Innovation, Firm Size and Employment Generation in Uruguay: The Microeconometric Evidence". IADB. CINVE, Montevideo.

Agencia Nacional de Investigación e Innovación (ANII) (2014). "Impacto de los instrumentos de promoción de la innovación orientada al sector productivo. Informe de Evaluación." DT Nº 7. ANII, Montevideo.

Altomonte, C. Gamba, S. Mancusi, M. L. Vezzulli, A. (2016). "R&D investments, financing constraints, exporting and productivity". *Economics of Innovation and New Technology*, *25*(3), 283-303.

Arocena, R. Sutz, J. (2010) "Weak knowledge demand in the South: learning divides and innovation policies". *Science and Public Policy*, 37(8): 571–582.

Arrow, K. (1962). "Economic Welfare and the Allocation of Resources for Invention". In: Arrow, K., Nelson, R., (Eds.), *The Rate and Direction of Inventive Activity*.

Balasubramanian, N. Lee, J. 2008 "Firm age and innovation" *Industrial and Corporate Change* 17(5): 1019-1047.

Becker, B. (2015). "Public R&D policies and private R&D investment: A survey of the empirical evidence". *Journal of Economic Surveys*, *29*(5), 917-942.

Benavente, J.M. Crespi, G. Maffioli, A. (2007), 'Public Support to Firm Innovation: The Chilean FONTEC Experience,' OVE WP 0407, IADB.

Bértola, L. Bianchi, C. Darscht, P. Davyt, A. Pittaluga, L. Reig, L. N. Román, C. Snoeck, M. Willebald, H. (2005). "Ciencia, Tecnología e Innovación en el Uruguay. Diagnóstico, Prospectiva y Políticas." DT Nº 26, UDELAR. Montevideo.

Bianchi, C. (2007). Capacidades de innovación en la industria manufacturera uruguaya. 1985-2003. Tesis de Maestría en Historia Económica. PHES, FCS, UDELAR, Montevideo.

Bianchi, C. Gras, N. Sutz, J. (2011). "Make, buy and cooperate in innovation: evidence from Uruguayan manufacturing surveys and other innovation studies". In: 2011. Crespi, G. Cimoli, M. "National innovation surveys in Latin America: empirical evidence and policy implications. CEPAL - IDRC LC/W.408, , Santiago de Chile.

Bianchi, C. Bianco, M. Snoeck, M. (2014). "Value attributed to STI Activities and Policies in Uruguay", in: Crespi, G., Dutrénit, G., (Eds) *STI Policies for Development: the Latin American Experience*. Springer. New York, pp 133-155.

Bianchi, C. Lezama, G. Peluffo, A. (2015) "Determinantes de la innovación en la industria uruguaya 1998-2009". Serie Documentos de Trabajo, DT 07/2015. IECON-FCEA-UDELAR, Montevideo.

Bianchi, C. Pittaluga, L. Fuentes, G. (2016). "¿Qué capacidades requieren las nuevas políticas de innovación y cambio estructural en Uruguay?" IADB, Washington D.C. DOI: http://dx.doi.org/10.18235/0000530

Binelli, C. Maffioli, A. (2007). "A Micro-econometric Analysis of Public Support to Private R&D in Argentina". *International Review of Applied Economics*, *21*(3), 339-359.

Bittencourt, G., (2012a). "IV Encuesta de Actividades de Innovación en la Industria Uruguaya (2007-2009)". ANII, Montevideo.

Bittencourt, G (2012b) "II Encuesta de Actividades de Innovación en Servicios en Uruguay (2007-2009)". ANII, Montevideo.

Bontempi, M. E. (2016). "Investment–uncertainty relationship: differences between intangible and physical capital". *Economics of Innovation and New Technology*, *25*(3), 240-268.

Borrás, S. Edquist, C (2013) "The choice of innovation policy instruments". *Technological Forecasting & Social Change*. 80. 1513-1522

Cassoni, A. Ramada, M. (2013). "Innovativeness along the business cycle". Documento de Investigación Nro, 93. ORT, Montevideo.

Cassoni, A. (2012). "The innovative behaviour of Uruguayan firms–stylized facts revisited". Documento de Investigación Nro, 82. ORT, Montevideo.

Chaminade, C. Edquist, C. (2010). "Rationales for public policy intervention in the innovation process: A systems of innovation approach". *The theory and practice of innovation policy. An international research handbook*, 95-114.

Chudnovsky, D. López, A. Rossi, G. 2008. "Foreign direct investment spillovers and the absorptive capabilities of domestic firms in the Argentine manufacturing sector (1992–2001)". *The Journal of Development Studies*, 44(5), 645-677.

Chudnovsky, D. López, A. Rossi, M. Ubfal, D. (2006a), "Evaluating A Program of Public Funding of Private Innovation Activities. An Econometric Study of FONTAR in Argentina" OVE WP 1606, IADB.

Chudnovsky, D. López, A. Pupato, G. (2006) "Innovation and productivity in developing countries: A study of Argentine manufacturing firms' behavior (1992–2001)." *Research Policy* 35(2): 266-288.

Cohen, W. 2010. "Fifty years of empirical studies of innovative activity and performance". In: Hall, B. Rosenberg, N. (Eds) *Handbook of the Economics of Innovation* (Vol. 1), 129-213, Elsevier, Amsterdam.

Crespi, G. Giuliodori, D. Giuliodori, R. Rodríguez, A. (2016) "The effectiveness of tax incentives for R&D+i in developing countries: The case of Argentina". *Research Policy*, http://dx.doi.org/10.1016/j.respol.2016.07.006

Crespi, G. Zuniga, P. 2012. "Innovation and productivity: evidence from six Latin American countries". *World Development* 40(2) 273-290.

Crespi, G. Tacsir, E. (2012). "Effects of innovation on employment in Latin America". Inter-American Development Bank. Technical Note No. IDB-TN-496.

Crespi, G. Maffioli, A., Mohnen, P. Vázquez, G. (2011). "Evaluating the impact of science, technology and innovation programs: a methodological toolkit". Inter-American Development Bank.

Cunningham, P. Laredo, P. Gök, A. (2013) "The Impact of Direct Support to R&D and Innovation in Firms" Nesta Working Paper 13/03.

Cunningham, P. Edler, J. Flanagan, K. Laredo, P. (2013b) "Innovation policy mix and instrument interaction: a review". Nesta Working Paper 13/20.

David, P. Hall, B. Toole, A. (2000), 'Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence,' *Research Policy*, 29, 497–529.

D'Este, P. Rentocchini, F. Vega-Jurado, J. (2014) "The Role of Human Capital in Lowering the Barriers to Engaging in Innovation: Evidence from the Spanish Innovation Survey", *Industry and Innovation*, 21:1, 1-19

D'Este, P. Iammarino, S. Savona, M. von Tunzelmann, N. 2012. "What Hampers Innovation? Revealed Barriers versus Deterring Barriers." *Research Policy* 41 (2): 482–88.

Fagerberg, J. Srholec, M. Verspagen, B. (2010). "Innovation and economic development". *Handbook of the Economics of Innovation*, *2*, 833-872.

Freitas, I. B., Castellacci, F., Fontana, R., Malerba, F. Vezzulli, A. (2017). "Sectors and the additionality effects of R&D tax credits: A cross-country microeconometric analysis". *Research Policy*, *46*(1), 57-72.

García-Quevedo, J. (2004). "Do public subsidies complement business R&D? A meta analysis of the econometric evidence". *Kyklos*, *57*(1), 87-102.

Gök, A. Edler, J. (2012). "The use of behavioural additionality evaluation in innovation policy making". *Research Evaluation*, rvs015.

Guerzoni, M., Raiteri, E. (2015). "Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix". *Research Policy*, *44*(3), 726-747.

Hall, B. Lerner, J. (2010). "The financing of R&D and innovation". *Handbook of the Economics of Innovation*, *1*, 609-639.

Hægeland, T. Møen, J. (2007) "The relationship between the Norwegian R&D tax credit scheme and other innovation policy instruments". Statistics Norway, Oslo.

Huergo, E. Moreno, L. (2014). “National or international public funding? Subsidies or loans? Evaluating the innovation impact of R&D support programmes”. MPRA Paper No. 54218.

Hyytinen, A. Toivanen, O. (2005). “Do financial constraints hold back innovation and growth?: Evidence on the role of public policy”. *Research Policy*, *34*(9), 1385-1403.

Kannebley, S. De Prince, D. (2015). "Restrição financeira e financiamento público à inovação no Brasil: uma análise com base em microdados da PINTEC". *Nova Economia*, *25*(3), 553-574.

Klette, T. Møen, J. Griliches, Z. (2000). “Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies”. *Research Policy*, *29*(4), 471-495.

Köhler, C. Laredo, P. Rammer, C. (2012) "The Impact and Effectiveness of Fiscal. Incentives for R&D" Nesta Working Paper No. 12/01.

Lasarga, E. Rosich, L. Rueda, H. (2015). “Evaluación de impacto de las políticas de incentivo a la actividad innovadora en el sector industrial uruguayo”. DIE 02/15. IECON-FCEA-UDELAR, Montevideo.

Mairesse, J. Mohnen, P. (2010)“Using innovation surveys for econometric analysis”, in: Hall, B. Rosenberg, N. (eds), *Handbook of the Economics of Innovation*, Elsevier, Amsterdam, 1130-1155.

Marín, A. Sasidharan, S. (2010). "Heterogeneous MNC subsidiaries and technological spillovers: Explaining positive and negative effects in India". *Research Policy*, 39(9), 1227-1241.

Marino, M., Lhuillery, S., Parrotta, P., Sala, D. (2016). “Additionality or crowding-out? An overall evaluation of public R&D subsidy on private R&D expenditure”. *Research Policy*, *45*(9), 1715-1730.

Mazzucato, M. (2016). “From market fixing to market-creating: a new framework for innovation policy”. *Industry and Innovation*, 23(2), 140-156.

Neicu, D., Teirlinck, P., Kelchtermans, S. (2016). “Dipping in the policy mix: Do R&D subsidies foster behavioral additionality effects of R&D tax credits?” *Economics of Innovation and New Technology*, *25*(3), 218-239.

Nelson, R. (1959). “The simple economics of basic scientific research”. *Journal of Political Economy*. 49, 297–306.

OECD (2011) "ISIC Rev. 3 Technology Intensity Definition". https://www.oecd.org/sti/ind/48350231.pdf.

Østergaard, C. Timmermans, B. Kristinsson, K. 2011. "Does a different view create something new? The effect of employee diversity on innovation". *Research Policy*, 40 (3) 500-509.

Paunov, C. (2012). “The global crisis and firms’ investments in innovation”. *Research Policy*, *41*(1), 24-35.

Peluffo, A. Silva, E. (2016) “New stuff or better ways: what matters to survive international markets?” Jornadas de Economía, BCU, Montevideo.

Radicic, D. Pugh, G. T. Hollanders, H. Wintjes, R. (2014). "The impact of innovation support programmes on SME innovation in traditional manufacturing industries: an evaluation for seven EU regions." UNU-Merit Working Papers. 2014/033

Raymond, W. Mohnen, P. Palm, F. Van Der Loeff, S. (2010). “Persistence of innovation in Dutch manufacturing: Is it spurious?” *The Review of Economics and Statistics*, *92*(3), 495-504.

Resnichenko, I. (2017). "La relación entre el comportamiento innovador y la exportación en las empresas de la industria uruguaya (2004-2012)". Maestría en Economía y Desarrollo Industrial. Universidad Nacional General Sarmiento, Buenos Aires, Argentina.

Roper, S. Hewitt-Dundas, N. 2008. “Innovation persistence: Survey and case-study evidence”. *Research Policy*, 37(1), 149-162. DOI: 10.1016/j.respol.2007.10.005

Stiebale, J. Reize, F. 2011 "The impact of FDI through mergers and acquisitions on innovation in target firms." *International Journal of Industrial Organization*, 29(2), 155-167.

Szczygielski, K. Grabowski, W. Pamukcu, M. T. Tandogan, V. S. (2017). “Does government support for private innovation matter? Firm-level evidence from two catching-up countries”. *Research Policy*, *46*(1), 219-237.

Takalo, T. (2013) "Rationales and Instruments for Public Innovation Policies". Bank of Finland Research Discussion Paper No. 1/2013.

Thornhill, S. 2006. “Knowledge, innovation and firm performance in high-and low-technology regimes”. *Journal of business venturing*, 21(5), 687-703.

Zuniga, P. Crespi, G. 2013. “Innovation strategies and employment in Latin American firms”. Structural Change and Economic Dynamics, 24, 1-17.

Zúñiga-Vicente, J. Á., Alonso-Borrego, C., Forcadell, F. J., Galán, J. I. (2014). “Assessing the effect of public subsidies on firm R&D investment: a survey”. *Journal of Economic Surveys*, *28*(1), 36-67.

Annex

Table A1. Determinants to access public funding (linear probability model)

	(A0)
Innovation investment as a proportion of sales (t-3)	-0.00975
	(0.157)
Cooperated with other firms (t-3)	0.120*
	(0.0729)
Cooperated with research institutions (t-3)	-0.0444
	(0.0502)
Invested in disembodied innovation (t-3)	0.0879***
	(0.0339)
Number of employees (in logs)	0.000366
	(0.000461)
High technology	0.0691
	(0.252)
Service	-0.242***
	(0.0616)
Faced financial obstacles to innovation	-0.0201
	(0.0378)
Age	0.00246**
	(0.00122)
Number of employees (in logs)	0.0923
	(0.0710)
Foreign capital	-0.0669
	(0.0959)
Belongs to a group	0.0804
	(0.0501)
Constant	-0.538
	(0.328)
Year fixed effects	Y
Firm fixed effects	Y
Observations	1,142
Number of firms	660
R-squared	0.213

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)

	Linear			Log-linear		
	(A1)	(A2)	(A3)	(A4)	(A5)	(A6)
Public support	1.880***	1.901***	0.711*			
	(0.415)	(0.413)	(0.392)			
Public support (in logs)				0.170***	0.157***	0.113***
				(0.0190)	(0.0197)	(0.0275)
Cooperated with research institutions (t-3)	-2,267	-1,706	-6,876*	-0.00963	-0.0940	0.0372
	(2,996)	(3,522)	(4,104)	(0.149)	(0.153)	(0.244)
Cooperated with other firms (t-3)	4,225	5,966	2,750	0.451***	0.195	-0.0571
	(3,527)	(4,296)	(4,082)	(0.148)	(0.231)	(0.371)
Export intensity	11,222*	11,257*	7,813	0.682***	0.712***	-0.135
	(5,811)	(5,931)	(9,896)	(0.216)	(0.217)	(0.767)
Number of professionals	25.86	26.08	41.38	-0.000340	-0.000362	0.00264
	(31.67)	(31.55)	(55.03)	(0.000434)	(0.000433)	(0.00174)
Number of employees (in logs)	8,462***	8,340***	22,801**	0.683***	0.695***	0.751*
	(1,798)	(1,828)	(9,806)	(0.0630)	(0.0631)	(0.399)
High technology	307.8	120.1	-1,495	0.155	0.163	0.288
	(2,036)	(2,015)	(6,002)	(0.158)	(0.160)	(0.851)
Service	-2,801	-2,332	-2,031	-0.626***	-0.705***	-0.933***
	(4,258)	(4,648)	(4,089)	(0.183)	(0.186)	(0.297)
Age	6.488	6.321	89.66	0.00672**	0.00687**	0.00446
	(80.02)	(79.07)	(98.80)	(0.00312)	(0.00311)	(0.00701)
Foreign capital	-14,002**	-14,051**	-19,487	0.0344	0.0318	-0.709
	(6,249)	(6,249)	(12,455)	(0.194)	(0.194)	(0.511)
Belongs to a group	18,359**	18,267**	7,433	0.394**	0.393**	-0.698*
	(7,906)	(7,900)	(11,293)	(0.186)	(0.187)	(0.358)
Faced financial obstacles to innovation	-4,473	-4,493	10,121	-0.296**	-0.281**	0.255
	(2,907)	(2,977)	(6,961)	(0.133)	(0.133)	(0.230)
Constant	-29,989***	-30,766***	-99,400**	3.648***	3.415***	3.809**
	(7,772)	(8,527)	(46,577)	(0.276)	(0.308)	(1.826)
Year fixed effects	N	Y	Y	N	Y	Y
Firm fixed effects	N	N	Y	N	N	Y
Observations	1,143	1,143	1,143	1,143	1,143	1,143
R-squared	0.112	0.112	0.042	0.252	0.257	0.094
Number of firms	660	660	660	660	660	660

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

Source: authors based on UIS database

Table A3. Heterogeneous effects estimations (linear)

	(7)	(8)
Public support	1.489***	0.751*
	(0.425)	(0.393)
Firm has more than 100 employees	7,983	
	(9,742)	
Public*More than 100 emp	-0.919	
	(0.618)	
High technology	2,760	-1,193
	(6,966)	(6,759)
Public*Hi-tech		0.240
		(1.136)
Cooperated with research institutions (t-3)	-10,329**	-10,122**
	(4,841)	(4,834)
Cooperated with other firms (t-3)	3,424	4,064
	(4,732)	(4,942)
Export intensity	8,868	7,781
	(12,161)	(12,770)
Number of professionals	88.93	86.01
	(56.54)	(54.34)
Gross value added per capita	-0.000557	-0.000360
	(0.00150)	(0.00145)
Number of employees (in logs)	25,817***	28,864**
	(9,676)	(12,471)
Service	-1,014	-805.4
	(5,197)	(5,193)
Age	77.19	77.32
	(100.4)	(100.4)
Foreign capital	-10,863	-9,416
	(9,201)	(8,851)
Belongs to a group	853.7	119.0
	(11,149)	(10,955)
Faced financial obstacles to innovation	10,186	9,966
	(8,169)	(7,995)
Constant	-122,900**	-132,356**
	(49,593)	(60,077)
Year fixed effects	Y	Y
Firm fixed effects	Y	Y
Observations	953	953
R-squared	0.064	0.062
Number of firms	553	553

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

Source: authors based on UIS database

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

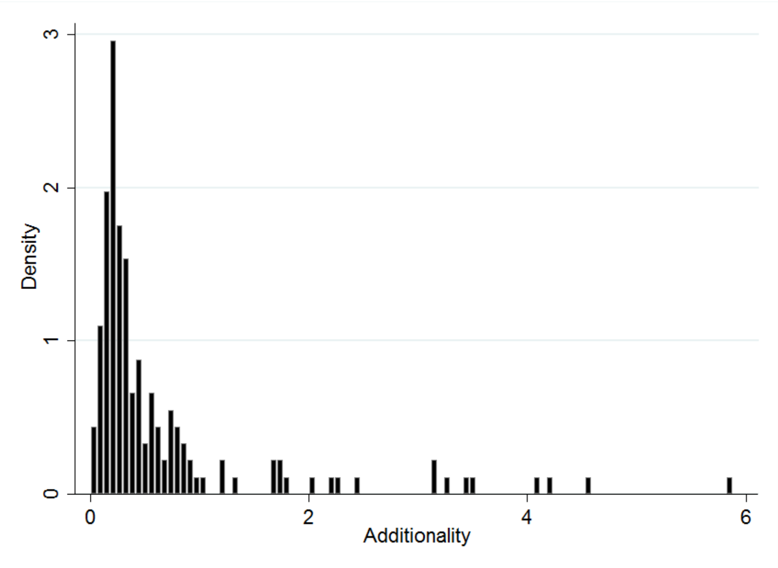


Table A4. Model estimations by type of innovation

	(A7) Disembodied linear	(A8) Embodied linear	(A9) Disembodied log-linear	(A10) Embodied log-linear
Public support	-0.0360	0.769*		
	(0.0783)	(0.400)		
Public support (in logs)			-0.00176	0.180***
			(0.0566)	(0.0491)
Cooperated with research institutions (t-3)	285.0	-7,062*	0.226	0.0146
	(882.2)	(4,022)	(0.393)	(0.449)
Cooperated with other firms (t-3)	1,478	710.1	0.0801	0.321
	(1,383)	(3,785)	(0.547)	(0.674)
Export intensity	1,633	4,407	2.078*	-0.570
	(1,420)	(9,653)	(1.086)	(1.147)
Number of professionals	-31.41	72.89	-0.00752***	0.00353*
	(31.82)	(51.58)	(0.00226)	(0.00195)
Number of employees (in logs)	1,172	21,226**	-0.322	0.751
	(985.5)	(9,600)	(0.658)	(0.738)
High technology	1,630	-4,078	2.165*	0.0108
	(1,195)	(5,716)	(1.299)	(2.075)
Service	-1,149	-849.3	-0.975*	-0.678
	(1,264)	(3,827)	(0.542)	(0.624)
Age	61.39	22.43	-4.31e-05	0.00418
	(57.24)	(61.06)	(0.0173)	(0.0146)
Foreign capital	976.0	-21,458*	-0.806	-0.643
	(1,059)	(11,718)	(0.966)	(0.969)
Belongs to a group	1,859	5,112	0.109	-0.753
	(2,858)	(10,087)	(0.527)	(0.597)
Faced financial obstacles to innovation	133.7	9,935	0.217	0.791*
	(330.4)	(6,982)	(0.364)	(0.445)
Constant	-5,876	-91,480**	4.553	1.946
	(5,398)	(45,532)	(2.992)	(3.322)
Year fixed effects	Y	Y	Y	Y
Firm fixed effects	Y	Y	Y	Y
Observations	1,143	1,143	1,143	1,143
R-squared	0.013	0.049	0.032	0.071
Number of firms	660	660	660	660

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

Source: authors based on UIS database

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