Public support prevalence and innovation behavior. Uruguay 2007-2015.

Gelabert, Liliana[1]
IE University

Pereyra, Martín[2]
Universidad ORT Uruguay
CINVE

Roldán, Flavia[3]
Universidad ORT Uruguay

Agosto 2021

Abstract

Using Uruguayan data from 2007 to 2015, we examine the role of the distribution of public support within sectors on the firm innovation efforts. Our empirical analysis shows that the manner in which public support is allocated within a sector affects a firm's incentives to undertake innovation expenditures. When public support for innovation activities is more equitably distributed within a sector, firms that persistently undertake innovation activities increase their innovation expenditures, whether or not they are direct recipients of support. These results highlight a new indirect mechanism by which innovation policy affects a firm's incentives to undertake private innovation.
Keywords: Innovation Policy; Innovation Expenditure; Latin America.
JEL codes: Ll0; Ll2

Documento de Investigación, Nro.127, agosto 2021. Universidad ORT Uruguay.
Facultad de Administración y Ciencias Sociales. ISSN 1688-6275.

[1] IE University (liliana.gelabert@ie.edu)
[2] CINVE & Universidad ORT Uruguay (pereyra_m@ort.edu.uy)
[3] Universidad ORT Uruguay (roldan@ort.edu.uy)

1. INTRODUCTION

It is widely accepted in the field of economics that technological progress is the key driver of economic growth. Schumpeter's growth model (Schumpeter, 1942) is grounded on the assumption that innovation, operationalized through the process of "creative destruction", determines economic growth and Neoclassical growth models identify technical change as the key factor sustaining per capita income growth (Solow, 1956). Economic theory has also shown that under free-market conditions, firms underinvest in research and development (R&D) activities due to imperfect appropriability of returns to R&D, as well as due to information problems that lead to incomplete markets (Nelson, 1959; Arrow 1962). In this context, government intervention by means of a diverse set of policy instruments (public subsidies, loans, tax credits) can potentially alleviate market failures and increase incentives for firms to undertake private R&D. During the last several decades, use of policy instruments to foster private R&D investment has gained prevalence in many countries (Dumont, 2017). Thus, the evaluation of such policies is relevant for policymakers, and a large body of empirical research has been produced to assess the impact of innovation policies. Yet despite strong theoretical arguments supporting the potential of public policies to foster innovation, existing empirical evidence evaluating the impact of such policies has revealed mixed results (David et al., 2000; Hall and Van Reenen, 2000; Zúñiga-Vicente et al., 2014; Becker, 2015).

This paper aims to illuminate the reasons for heterogeneity in business responses to innovation policy. Our broad goal is to improve innovation policy design. As noted above, the traditional argument justifying the allocation of public grants for innovation activities is that such grants reduce the private costs of innovation projects that have social spillovers. Even in the absence of spillovers, public support can still be justified to address those capital market imperfections that lead firms to underinvest in R&D. When correctly allocated, public support for R&D can incentivize private R&D by reducing its (private) cost and/or by providing funding that would not be accessible for such purposes through capital markets. In this paper, we suggest that in addition to the two direct channels for incentivization of private R&D, an alternative indirect mechanism also exists that can increase private incentives to undertake innovation

activities. We argue that the impact of innovation policies on firms' incentives to invest in innovation is affected not only by whether a firm has received public support or not, but also by the distribution of public support for other firms in a given sector. More precisely, we suggest that ceteris paribus, a more dispersed allocation of public support within a sector may induce firms to believe that a significant number of other firms within the sector are active in a sectoral innovation race, and to expect, therefore, that competition will be intense because of strong innovation activity within the sector. The expectation of a high level of competition resulting from the existence of public support will induce firms to change innovation efforts. Moreover, we claim that a firm's response to public support will depend on its own innovation experience: firms that persistently undertake innovation activities will be incentivized to increase innovation efforts when public support is prevalent in their sectors.

This paper contributes to existing innovation literature in several respects. First, from a theoretical point of view, we suggest a new source of policy impact on innovation outcomes: the level of sectoral dispersion of public support. This new mechanism implies not only that firms receiving public support could respond to it, but also that non-recipients of public support (i.e., non-treated firms) might have incentives to change their innovation effort, since they perceive public support within their sector as a signal of potential competition. Accounting for how the indirect channel can influence innovation outcomes provides an additional explanation for the heterogeneous results reported in previous innovation policy evaluation literature. Moreover, it can encourage better design of innovation policies. More broadly, our paper contributes to improved understanding of the relationship between innovation and competition policies. The indirect mechanism we have identified suggests that innovation policies can be used to incentivize competition when public grants are allocated in a dispersed way, increasing the positive impact of given policies among firms that are active in sectoral innovation races. Our results also underscore the importance of considering a firm's stance vis-à-vis the technological frontier (Aghion et al., 2005) when seeking to understand the relationship between competition and innovation activities. Finally, from an empirical point of view, we contribute to the existing literature by providing empirical evidence from a developing country. The innovation literature has highlighted the need to adjust innovation policies to a country's stage of development (Acemoglu et al., 2006: Aghion and Roulet, 2014). Thus, it is important to test theoretical predictions

using data from countries with varying development profiles. Uruguay is an interesting case, since it is a small and open economy in Latin America, located between two large neighbors, Argentina and Brazil, that have historically strongly influenced its economy. Uruguay's small domestic market represents a significant limitation to profit from innovation activities. In addition, Uruguay's vulnerability to external shocks stemming from its neighbors represents an additional challenge for firms evaluating whether to undertake innovation activities.

The database used in our empirical analysis allows us to test our theoretical predictions for both manufacturing and service firms. Although the service sector is increasingly important in developed and developing countries, accounting for around 65% of world GDP (World Bank, National Account Database), the empirical literature has frequently focused on manufacturing alone. The determinants of innovation in services are thus not well documented. Our study can contribute to a better understanding of the differences between manufacturing and service firms in terms of their responses to innovation policies. Our results show that while the impact of public support on private innovation expenditures is qualitatively similar for manufacturing and service firms, the magnitude of the effect of such support is significantly stronger in services than in manufacturing.

The remainder of the paper is organized as follows. Section 2 describes related literature. Section 3 presents data and empirical methods. Section 4 reports results, while Section 5 offers extensions and robustness checks. Section 6 concludes.

2. LITERATURE REVIEW

Governments have long played a significant role in encouraging, and providing financial support for, private innovation activities. Scholars have put forth two main economic rationales for the provision of public support for innovation activities. Kenneth Arrow (1962) determined that private firms take into account the imperfect appropriability of knowledge production when deciding to undertake innovation expenditures, leading them to underinvest in such activities relative to socially optimal outcomes (Arrow 1962). In addition, R.R. Nelson (1959) and Arrow (1962) determined that capital market imperfections often constrain firms' ability to access external financing for innovation, since innovation activities, particularly R&D, are risky and challenging to evaluate ex-ante. More recent empirical evidence has shown that small

and young firms are particularly vulnerable to such market constraints (Hall and Lerner, 2010). Although public support can potentially alleviate these market failures, certain forces, work against its effectiveness[4].

Extensive empirical literature has addressed whether public support policies for innovation activities lead to higher private innovation expenditures, or to crowding-out. The existing evidence is mixed (see Zúñiga-Vicente et al., 2014, and Becker, 2015, for recent surveys)[5]. Although most research indicates that industrial policy instruments designed to correct market failures have positive and significant effects (e.g., Hall and Van Reenen, 2000; Lach, 2002; Almus and Czarkitzki, 2003; Bronzini and Piselli, 2016), some relevant contributions support the existence of crowding-out (e.g., Wallsten, 2000) or find no significant effect (e.g., Klette and Moen, 1999; Marino et al., 2016).

Researchers have pointed to various factors to explain conflicting results with respect to the impact of government policies on innovation. Besides using different econometric techniques, conflicting evidence regarding the effectiveness of innovation policies can derive from the fact that governments use different policy tools when implementing innovation policy, while most impact evaluation studies focus on just one tool. This fact has spurred an exciting but small branch of research within which this paper fits: understanding which dimensions in industrial policy design can increase policy effectiveness. There are multiple dimensions through which one can analyze industrial policy design in the context of innovation activities. Several authors have identified the policy mix of instruments (direct/indirect funding) as a relevant characteristic of programs encouraging innovation activities (Busom et al., 2015, Guerzoni and Raiteri, 2015, and Huergo and Moreno, 2017). For instance, Guellec and Van Pottelsberghe de la Potterie (2003) have found substitutability, and Haegeland and Moen (2007) have found complementarity between direct and indirect public support to innovation. In the same line of exploration of interactions among innovation policy

[4] On the one hand, firms might have incentives to ask for public support (particularly if application costs are low) even for projects that would be privately profitable in the absence of external support. In such cases, public support can substitute for private expenditures ("crowding-out" effect). This misallocation of public support is facilitated by the fact that public agencies often face significant informational asymmetry with respect to private firms when evaluating the private and social returns of given projects. In addition, opportunistic government agencies appear to have incentives to finance privately profitable projects in order to convey an image of policy effectiveness, thus enhancing the reputations of the agencies themselves ("cherry-picking"). These sources of “crowding-out” can lead to the failure of innovation policy (Besanko et. al, 2018; Dimos and Pugh, 2016).

[5] For Uruguay, see Aboal and Garda (2015), and Bukstein et al. (2015).

tools, Gelabert et al. (2009) showed that public support policies for innovation are more effective in increasing private R&D expenditures in firms for which intellectual property rights (IPR) mechanisms are relatively ineffective, suggesting some level of substitution between these two instruments. More recently, Dumont (2017) found that the effect of R&D support policies decreases with the number of instruments each firm receives, especially if firms obtain both subsidies and tax benefits, again suggesting some degree of substitutability between different policy tools.

Various authors have examined the existence of intertemporal tradeoffs as determinative of the effectiveness of given policy instruments. Acemoglu et al. (2006) argue that one type of industrial policy that might work in countries at early stages of development (i.e., those policies that support investment-based strategies) could have the long-run effect of not allowing economies to approach the technology frontier quickly. Acemoglu et al. (2018) find that taxing incumbent firms can promote the exit of less productive firms, and thereby, free up skilled labor. This fact triggers a reallocation mechanism by which skilled labor is used for R&D purposes by high-performing incumbents. The authors argue that one cannot reach such an objective by subsidizing incumbents' R&D efforts, because this would encourage the survival and expansion of relatively inefficient firms. From a broader perspective, Aghion and Roulet (2014) argue that as economic growth strategy shifts from imitation to innovation, countries require different policies and institutions.

As noted in the introduction, our research explores the effects of the distribution of public support within a sector on individual firms' willingness to undertake innovation. We claim that the distribution of such financial aids affects the expectation of competition faced by the firms within their sector. Thus, our work relates to the literature on the effects of product market competition on innovation. What the impact of competition on innovation might consist of, has been a persistent question in economics since Schumpeter argued that competitive markets do not necessarily constitute the best circumstances for innovation to flourish (Gilbert, 2006). Following Arrow (1962), Holmes et al. (2012) proposed an alternative rationale for why monopolies might innovate less. Focusing on switchover disruptions (i.e., the idea that upon adoption of technology, firms might temporarily reduce output), the authors argue that the cost of innovation is the opportunity cost of foregone output units, which increases with monopoly power. Recently, a consensus seems to have developed that a

competitive environment influences firms' decisions to innovate, but not necessarily in a linear manner. Aghion et al. (2005), IMF (2019) among others, find evidence of an inverted-U relationship between innovation and product market competition. Moreover, Bloom et al. (2016) investigate the impact of Chinese import competition on measures of innovation output: they conclude that the absolute volume of innovation increases for firms most affected by Chinese imports in their output markets. For Uruguay, De Elejalde et al. (2018) find a negative and significant impact of competition on resources devoted to innovation activities, but strong evidence of a positive and significant effect of competition on the efficiency of innovation expenditures.

This study finds that the manner in which public support for innovation activities is allocated within a sector affects the innovation activities of firms in the sector. We argue that more evenly distributed public financial support for innovation induces firms to believe that they will suffer competition. Thus, a relatively even distribution of public support may impact all firms through the indirect mechanism of changing beliefs regarding the strength of within-sector innovation races. Thus, the manner in which public support is allocated within a sector is a relevant dimension for innovation policy design.

To predict a firm's response to the perceived threat of competition stemming from public resource distribution, we integrate aspects of the literature on the impact of market competition on innovation efforts. In particular, we draw from Aghion et al. (2005), highlighting the importance of taking technological distance to the frontier into account as an important factor in explaining the relationship between competition and innovation. By incorporating this concept in our analysis, we find that firms far from the technological frontier are less sensitive to the threat of more evenly distributed public support than firms closer to the frontier.

The current study is closely related to Aghion et al. (2015), who argue that competition-friendly industrial policies (i.e., support allocated to competitive sectors or granted to foster competition in a sector) can increase innovation and productivity growth, thus suggesting some complementarity between competition and innovation policies. The notion of complementarity is confirmed by the authors' empirical analysis using Chinese data. Our study adds new insight to Aghion et al.'s (2015) results by showing that competition-friendly innovation policies do not always incentivize innovation efforts, but they do so only among more persistent innovators.

3. DATA AND METHODS

a. Data sources

We use publicly available Uruguayan data from the Business Innovation Survey (BIS) between 2007 and 2015. The BIS is a joint effort conducted by the National Institute of Statistics (INE) and the National Agency for Innovation and Research (ANII). It has been specially designed to identify a firm's innovation activities, and thus it provides better measures to characterize the innovation process than alternative sources such as industrial surveys or administrative data. Moreover, the BIS includes information from both manufacturing and services sectors, for which existing empirical evidence in the innovation literature is very scarce. Firms with more than five employees are sampled from the population, while all firms that have ever received public support must participate. The information collected from the survey reveals innovation expenditures, human resources assigned to innovation activities, innovation activity outcomes, sources of funding for innovation activities, cooperation agreements, and network participation, among other factors. The survey is performed every three years, although some variables are reported yearly. For other variables, firms are asked to report averages for given periods. Our sample is composed of 3,109 firms and 14,830 observations.

b. Empirical Strategy

This paper explores the role of the distribution of public support within a sector on individual firms' innovation efforts. As noted previously, we claim that the distribution of public support within a sector can affect a firm's beliefs regarding the threat of competition. Thus, distribution of support induces firms to change their innovation strategies. More precisely, a higher prevalence of public support within a sector will induce firms to conjecture that a higher number of competitors within the sector are active in innovation races, so competition will be more intense as a result of the stronger innovation activity within the sector. Consequently, the expectation of enhanced competition resulting from more generalized public support will induce firms to change their current innovation strategies.

The basic model regresses a measure of the prevalence of public support for innovation activities within a sector on the firm level of the innovation effort. The estimated equation for firm *i*, in industry *j*, at time *t*, is the following:

$$INNEFFORT_{ijt} = \alpha_1 PUBSUPPREV_{jt} + \alpha_2 X_{ijt} + \alpha_3 Z_{jt} + \eta_i + \eta_j + \eta_t + \varepsilon_{ijt},$$

where X_{ijt} is a vector of firm-level control variables, Z_{jt} is a vector of sector-level control variables, η_i is a firm's fixed effect, η_j is a sector's fixed effect, η_t is a time fixed effect and ε_{ijt} is a time-varying unobservable that affects the innovation activity of firm *i*, in sector *j* at time *t*. The coefficient of primary interest is α_1, reflecting the impact of a marginal change in the prevalence of public support for innovation activities within the sector to which the firm belongs on the firm's private innovation effort. Below we describe the variables included in the estimated models.

Private Innovation Effort. In the survey, firms are asked to report their total expenditures in innovation activities. These activities include R&D (internal and external), capital expenditures, technology transfers, industrial design, training, organizational design, and market research. Firms also have to report percentage breakdowns of different sources of funds: internal resources, other firms, public agencies, universities, and non-profit institutions. We compute privately financed innovation expenditures, the dependent variable in our empirical analysis (*INNEFFORT*), by subtracting the share of public funds for innovation activities from total innovation expenditures. Due to the skewness of the distribution, we use the logarithm of one plus this variable's level in our estimations.

Sectoral Public Support Prevalence. We compute a measure of sectoral public support prevalence by considering two relevant dimensions that describe the allocation of public support within a sector: the share of firms receiving public support and the distribution of public funds for innovation among supported firms within the sector. We proceed as follows.

We first construct a Herfindahl Index of innovation expenditures supported by the public sector:

$$HHI_{ijt}^{PUBSUP} = \sum_{k \epsilon j,\ k \neq i} \left(\frac{PUBSUP_{kjt}}{PUBSUP_{jt}} \right)^2,$$

where $PUBSUP_{kjt}$ is the amount of public support received by firm *k* in sector *j* (at the four-digit CIIU code) at time *t*, and $PUBSUP_{jt}$ is the amount of public support received in sector *j* at time *t*. To address the potential endogeneity of HHI_{ijt}^{PUBSUP} we compute this factor separately for each firm, excluding the firm's public support in both the numerator and denominator. Consequently, this sector-level measure is exogenous to firm *i*'s performance.

Then we define dispersion as:

$$Dispersion_{ijt} = \left(1 - HHI_{ijt}^{PUBSUP}\right); \qquad Dispersion_{ijt} \in [0,1],$$

where higher values indicate a more equal distribution of public support across supported firms within a sector.[6] Since this variable's objective is to proxy how prevalent public support is within sectors, we combined the dispersion variable that accounts for the distribution of public support within supported firms with information regarding the share of firms receiving public support for innovation. Therefore, the final measure of sectoral public support prevalence weights the dispersion variable by the share of supported firms within the sector and is defined as:

$$PUBSUPPREV_{ijt} = Dispersion_{ijt}\ x\ \frac{\left(\#\ firms\ receiving\ public\ support_{jt}\right)}{n_{jt}},$$

where $\#\ firms\ receiving\ public\ support_{jt}$ is the number of firms that received public support for innovation activities in sector *j* at year *t*, and n_{jt} represents the total number of firms in sector *j* and year *t*. Thus, the variable *PUBSUPPREV* increases with the level of dispersion in the allocation of public support within supported firms and with the number of firms receiving public support within the sector.[7]

Other variables related to public support. All the estimated models include a dummy variable indicating whether the firm received public support (D_PUBSUP). This variable takes the value of one if the firm received public support and zero otherwise. We also control for sectoral public support (*SECPUBSUP*) by constructing the following variable:

$$SECPUBSUP_{jt} = \frac{PUBSUP_{jt}}{PUBSUP_t} \qquad SECPUBSUP_{jt} \in [0,1],$$

[6] In case of minimal concentration, dispersion variable is equal to $\left(1 - \frac{1}{\#\ firms\ receiving\ public\ support_{jt}}\right)$.

[7] See the Appendix for details.

where $PUBSUP_{jt}$ is the amount of public support received by sector *j* at time *t*, and $PUBSUP_t$ is the total amount of public support across all sectors in the economy at time *t*.

Technological Gap. We build a proxy of a firm's technological gap by measuring the difference in labor productivity between that firm and the leading firm in its sector.

$$TECHGAP_{ijt} = \frac{(Prod\ Leading_{jt} - Prod_{ijt})}{Prod\ leading_{jt}},$$

where $Prod\ Leading_{jt}$ is the labor productivity for the most productive firm in sector *j* (at the four-digit CIIU code), and $Prod_{ijt}$ is the labor productivity of firm *i* from sector *j* at time *t*:

$$Prod_{ijt} = \frac{Sales_{ijt}}{Employees_{ijt}}.$$

Obstacles to Innovation. The survey reveals the obstacles to innovation faced by firms that have undertaken at least one innovation activity. Among the factors that hinder the development of innovation activities are difficulties with respect to the return period for innovation. These difficulties involve both market size and financing. Market size is a crucial issue for a small economy like Uruguay's. In addition, given that more than 90% of Uruguayan firms are small and medium-sized (ANII, various reports), they are significantly subject to financing constraints when they undertake innovation activities. We use the categorical information about this obstacle provided in the survey and compute a dummy variable (*D_OBSTRETURN*) that takes the value of one when the firm reports this obstacle to be of high to medium importance and 0 when it reports the obstacle to be of low or no importance.

Market Competition. We control for market competition (*COMPETITION*) by constructing the following variable. We start computing the Herfindahl-Hirschman Index (HHI) for sector *j* at time *t* as:

$$HHI_{jt} = \sum_{i=1}^{N_{jt}} s_{ijt}^2 \qquad HHI_{jt} \in [0,1],$$

where s_{ijt} is the market share (measured in sales) of firm *i* in sector *j* (at the four-digit CIIU code) at *t*, *HHI* of zero indicates that the market is perfectly competitive, and an

HHI of one means that a monopolist operates the market. To capture the degree of sectoral competition, we compute:

$$COMPETITION_{jt} = 1 - HHI_{jt},$$

so that an increase in the competition index reflects an increase in market competition. All specifications also include a quadratic term for *COMPETITION* to account for non-linear effects.

We control for a firm's ratio of exports to sales (*EXPSHARE*) as an indirect proxy for the level of exposure to competition that each firm faces. We also include age (*AGE*) as an additional control variable to proxy for firm experience. Finally, we control for firm size by using the logarithm of the total number of employees (*EMPLOYEES*) as a proxy. Firm size may be correlated with innovation efforts since larger firms may obtain greater benefits from economies of scale and scope (Cohen, 1995). Also, size could be related to financial constraints and has proven to be a critical determinant of firm innovation efforts (Hyytinen and Toivanen, 2005). For *EMPLOYEES* and *AGE* variables, we also include quadratic terms to account for possible non-linear effects.

In addition to the control variables described above, the level of innovation effort is also determined by a firm's unobserved innovation ability. To control for this source of unobserved heterogeneity, we include a firm's fixed effects, often an effective way to control for innovation ability that is likely to be stable over short periods. Finally, all specifications include year and sector dummies at the two-digit CIIU code. Conditional on the inclusion of these control variables, our underlying identification assumption is that shocks affecting the prevalence of public support within sectors are uncorrelated with shocks affecting firm innovation efforts.

Given that our sample includes both innovators and non-innovators, an important methodological issue to consider is the censored status of innovation expenditures. For around two-thirds of total observations, the dependent variable has the value of zero. In order to take this into account, we estimate a Tobit model. Unfortunately, when T (number of periods) is small, we cannot treat a firm's unobserved heterogeneity as a parameter to estimate because of the 'incidental parameters problem' that produces inconsistent estimates in non-linear models with fixed effects (as discussed in Neyman and Scott, 1948; Wooldridge, 2002). Greene (2004) shows that although the estimation bias for the slope parameters in the case of

Tobit models is not severe, the estimation of the disturbance variance is downward biased and would, therefore, be transmitted to the estimates of marginal effects. Thus, rather than treating unobserved effects as parameters to be estimated, we follow Chamberlain (1984) to model the distribution of unobserved effects conditional on the exogenous variables' average along time. This model allows the instrument to be systematically correlated with time-constant omitted factors.

c. Descriptive evidence

Table 1.a reports descriptive statistics of the variables described above for subsamples of firms in the manufacturing and services sectors. Around 60% of sampled firms belong to the service sector and 40% to the manufacturing sector. On average, firms in the manufacturing sector are more likely to spend privately on innovation activities and to receive public support for innovation than is the case with services firms. The prevalence of public support for innovation activities is also significantly higher in manufacturing sectors, which are less technologically dispersed (or, in other words, closer to the technological frontier), more likely to export, and more concentrated than service sectors. Finally, manufacturing firms have on average fewer employees and are older than service firms.

The sampled firms have different profiles in terms of innovation activities. For instance, 42% of our sample (37% in manufacturing and 45% in services) do not report any innovation expenditures during the analyzed period. Thus, to uncover and illustrate the innovation patterns of the sampled firms, we focus on firms that report positive innovation expenditures every year they are surveyed. We label these firms as "persistent innovators".

INSERT TABLES 1.a and 1.b ABOUT HERE

Table 1.b reports descriptive statistics for persistent innovators, representing around 12% of the entire sample for both the manufacturing and services sectors.

The median of private innovation expenditure (in Uruguayan pesos) for persistent innovators in the manufacturing sector is 2,673,650, and 2,017,427[8] in the service sector.

Sectoral public support prevalence is higher for firms undertaking innovation activities than for the sample as a whole. This fact holds for manufacturing and service firms.

There are no significant differences in the average level of technological dispersion within service sectors; however, persistent innovators are significantly less technologically dispersed than the overall manufacturing sample. In addition, persistent innovators face slightly more concentrated sectors than does the sample as a whole.

In terms of size, persistent innovators have significantly more employees, operate in sectors with higher export activity, and are older than the samples for either the manufacturing or service sector.

Overall, this descriptive evidence shows that firms that persistently spend resources on innovation activities are different in many important ways from those firms that only implement innovation activities intermittently or do not undertake any innovation efforts.

4. RESULTS

Table 2 reports the results of estimating the determinants of innovation effort measured as the logarithm of total innovation expenditures. Column (1) shows the results for manufacturing firms, while column (2) shows the estimates for services firms. For both samples, the coefficient for *PUBSUPPREV* is negative but not significant.

INSERT TABLE 2 ABOUT HERE

Regarding the control variables, for both manufacturing and services firms we find that receiving public support is associated with higher innovation expenditures, and that firms with a higher technological distance to the sector leader spend relatively less

[8] Given that the exchange rate between the Uruguayan peso and the American dollar (USD) was 28.78 Uruguayan pesos for each USD on December 31, 2017, median innovation expenditures for persistent firms in manufacturing were around USD 92,900, and in services around USD 70,100.

in innovation activities. The other control variables have the expected signs but are generally not significant, probably because we are controlling for firms' fixed effects, and these variables experience little variation during the analyzed period.

As described earlier, the purpose of this study is to test whether the way public support is allocated within a sector can influence a firm's innovation decisions. In particular, we claim that more equitable distribution of public support within a sector can encourage firms to believe that innovation races within the sector will be more competitive, in turn inducing the firms to change their innovation efforts. As described in the previous section, the sampled firms were very heterogeneous in their innovation activities. While some firms undertook innovation activities every year, other firms invested in innovation for only some years, and a large group of firms did not undertake innovation activities at all during the analyzed period. Considering that responses to the perception of increasing competition can differ across firms, we re-estimated the model focusing on the innovative behavior of persistent innovators.

Table 3 reports the results for persistent innovators that invested every year in the sample. We used a fixed-effects OLS model to estimate the effect of the prevalence of public support on innovation expenditures. We needed to consider the potential selection bias arising from restricting the estimation to the sample of persistent innovators. In order to test and eventually take this bias into account, we used a two-stage Heckman model (Heckman, 1979). In the first stage (models 1 and 3 from Table 3), we estimated a probit model for the probability of being a persistent innovator. With the estimated coefficients, we predicted the probability of being a persistent innovator for every firm in the sample, and in the second stage, we incorporated a transformation of these predicted probabilities as an additional explanatory variable. The inclusion of this additional control variable (the inverse Mills ratio) allowed us to test and correct for potential sample selection bias due to focusing only on the subsample of persistent innovators.

INSERT TABLE 3 ABOUT HERE

Models 2 and 4 from Table 3 report the results of the second stage of the Heckman model. The reported coefficients show that for both manufacturing and

service firms, an increase in public support prevalence within the sector leads to higher innovation expenditures by persistent innovators. In addition, the magnitude of the estimated coefficients indicates that an increase of one standard deviation in public support prevalence is associated with an almost 51% increase in private innovation expenditures in manufacturing firms and an almost 86% increase in private innovation expenditures among services firms. Finally, the inverse Mills ratio is strongly significant for both manufacturing and services firms, suggesting that controlling for the sample selection bias is required.[9]

In sum, the coefficient for *PUBSUPPREV* is not statistically significant when we consider the entire sample but is positive and strongly significant for persistent innovators. These results indicate that a higher prevalence of public support significantly affects those firms with innovation experience. Thus, firms that undertake innovation activities persistently are incentivized to increase their innovation expenditures to respond to the increasing threat of competition due to the prevalence of public support for innovation. These results are consistent with previous empirical work (see, for instance, Aghion et al. 2005), showing that firms respond differently to increases in the level of competition. Interestingly, the magnitude of the response to variation in public support prevalence for persistent innovators is larger for service firms than for manufacturing firms.

5. EXTENSIONS AND ROBUSTNESS TESTS

This section explores the existence of heterogeneous effects of the prevalence of public support and performs some robustness tests on our central specification. The results reported in the previous section show that an increased prevalence of public support is associated with higher private innovation expenditures among persistent innovators. We claim that a possible mechanism explaining this result is that more dispersed allocation of public support may induce firms (both those that receive and those that do not receive public support) to believe that a significant number of firms within the sector are active in sectoral innovation races. Therefore, these firms expect that competition will be more intense due to greater innovation activity within the

[9] In the Appendix, we include the descriptive statistics and the results of the main specification for non-persistent firms.

sector. Thus, the expectation of a higher level of competition resulting from the prevalence of public support will induce firms to change their innovation efforts. As described in Section 2, Aghion et al. (2005) suggest that to explain the responses of firms to heightened competition, one has to consider the heterogeneity of the firms in terms of productivity. Drawing on Aghion et al. (2005), we explored whether this estimated effect is heterogeneous across firms with respect to their distance to the technological frontier. To this end, we incorporated in the main specification for persistent innovators the interaction between public support prevalence and a firm's distance from the technological frontier. Results reported in Table 4 show that less productive firms, i.e., firms with higher technological gaps, are less sensitive to the threat of increased competition due to more evenly distributed public support. This is true for both manufacturing and service firms. These results are consistent with the idea that laggard firms (that is, firms that are further from the frontier) have fewer incentives to respond positively to the threat of increased competition than frontier firms, and that laggard firms will have a harder time catching up.

INSERT TABLE 4 ABOUT HERE

Another source of heterogeneous effects is firm exposure to international competition, which we explored by including the interaction between public support prevalence and export intensity. Results reported in Table 5 show that firms with lower levels of exposure to international competition are more sensitive to the effect of competition resulting from a greater prevalence of public support, compared to firms more focused on international markets. One possible explanation for this result is that firms less dependent on supplying the domestic market could be less sensitive to the increased threat of competition from domestic rivals arising from the higher prevalence of within-sector public support. This result would indicate that the mechanism suggested in this paper, by which the distribution of public support could influence incentives to innovate, is quantitatively more relevant for firms that compete mainly domestically. Firms that are significantly more exposed to international markets may be relatively less concerned about competitive dynamics occurring domestically as opposed to internationally. This result is also consistent with the fact that we find the

impact of public support prevalence to be stronger for services than for manufacturing firms since services are intrinsically less tradable than manufactured products.

INSERT TABLE 5 ABOUT HERE

Finally, we conducted a series of robustness checks to verify the reliability of the reported results. We re-estimated the key models reported in Tables 2 and 3 using alternative dependent variables. Specifically, we investigate the effect of public support prevalence on the following categories of innovation spending by firms: R&D activities (both internal and external), capital goods (i.e., machinery), and other minor categories (such as IT acquisition, training, product, and organizational design and consulting). The most important category is investment in capital goods, accounting for around 73.5% of all firm spending on innovation between 2007 and 2015. This fact reflects a distinctive characteristic shared by most Latin American countries (Cirera and Maloney, 2017). Investments in R&D and Other Categories account for around 9.5% and 17%, respectively[10].

Table 6 reports the estimated coefficient of public support prevalence for the alternative dependent variables and subsamples (the overall sample and persistent innovators). We find that when significant, the signs of the estimates of our variable of interest (*PUBSUPPREV*) are consistent with those reported in our main specification. Higher public support prevalence is associated with lower investments in capital goods for the entire sample for both manufacturing and service firms. However, once we focus on persistent innovators, public support prevalence leads to higher investment in capital goods among manufacturing and services firms.

INSERT TABLE 6 ABOUT HERE

---

[10] Our database does not allow us to disentangle which portion of funds invested in each category corresponds to private or public innovation efforts. Firms report the percentages of funding sources per period. One of the sources reported is public funding, but we cannot assume the same distribution for each category (i.e., R&D, capital goods, and others) over the period.

6. CONCLUSIONS

The literature on public support policies for private innovation is extensive. The traditional argument justifying the allocation of public grants for innovation activities is that such grants reduce the costs to private firms of implementing innovation projects with high social spillovers, thereby inducing private firms to undertake projects of benefit to society. The purpose of this paper is to show that public grants for innovation activities affect not only private innovation decisions through the direct channel of reducing costs for innovation, but also affect all firms in a given sector through the indirect channel of changing beliefs about the threat of competition.

More precisely, this paper shows that when public support is allocated more equitably within a sector (i.e., when more firms receive public support and/or when total support is relatively evenly distributed), persistent innovators increase innovation expenditures. In a nutshell, the analysis reported in this paper shows that: (i) not only the magnitude of public support received by a firm, but also the distribution of support within a sector, matters for the effectiveness of innovation policies, and (ii) firms will respond differently to the perceived threat of increased competition depending on their innovation experiences. Only persistent innovators will be incentivized to increase their innovation efforts when public support is more prevalent in their sectors. In particular, firms that are closer to the technological frontier and those more dependent on domestic markets will increase innovation. Our estimates suggest that a more equitable distribution of public support (a one standard deviation increase in public support prevalence) during the analyzed period could have increased average innovation expenditures by approximately 51% in manufacturing and 86% in services firms for persistent innovators.

These results are relevant for policy design, as they highlight a new channel through which public support can influence firm-level private innovation expenditures. Our suggested mechanism implies that not only treated firms, but also non-treated firms could respond to policy support. Examining the effects of this indirect channel contributes to innovation policy evaluation literature by providing an additional explanation for the heterogeneous results reported previously, and by suggesting methods to improve the design of innovation policies to boost effectiveness. The results

of this study also contribute to a better understanding of the relationship between innovation and competition policies. They underscore the importance of considering a firm's proximity to the technological frontier (Aghion et al., 2005) when seeking to explain the relationship between competition and innovation activities so widely studied within the field. Finally, we identify differences between manufacturing and services firms from the standpoint of the innovation process, which has not been explored sufficiently previously. The evidence reported in this study shows that the mechanism identified is significantly stronger for service than for manufacturing firms. This difference could be explained by the fact that services are much less exposed to international competition, and therefore, service firms are more responsive to competitive dynamics arising from the domestic market than are manufacturing firms.

The results reported in this study chart several paths for future research. For instance, we could try to better identify factors explaining the much stronger response to prevalent public support among services as compared with manufacturing firms. We could further explore the impact of competitive pressures on incentives to innovate depending on whether the pressures arise from domestic or foreign competitors. Finally, we might wish to examine whether the positive effect of prevalent public support on private incentives to spend on innovation identified in this study also holds in more advanced economies, where firms are less technologically dispersed and closer to the technological frontier. Answering these questions would contribute to better design of innovation policies and enhancement of their effectiveness.

REFERENCES

ABOAL, D. & GARDA, P. (2015). ¿La financiación pública estimula la innovación y la productividad?: una evaluación de impacto. *Revista de La CEPAL*, 115, 42–62.

ACEMOGLU, D., AGHION, P., & ZILIBOTTI, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic Association*, 4(1), 37–74.

ACEMOGLU, D., AKCIGIT, U., ALP, H., BLOOM, N. & KERR, W. (2018). Innovation, reallocation, and growth. *American Economic Review*, 108(11), 3450-91.

AGHION, P., BLOOM, N., BLUNDELL, R., GRIFFITH, R. & HOWITT, P. (2005). Competition and innovation: an inverted-u relationship. *The Quarterly Journal of Economics*, 120(2), 701-728.

AGHION, P., CAI, J., DEWATRIPONT, M., DU, L., HARRISON, A. & LEGROS, P. (2015). Industrial policy and competition. *American Economic Journal: Macroeconomics*, 7(4), 1–32.

AGHION, P. & ROULET, A. (2014). Growth and the smart state. *Annual Review of Economics*, 6(1), 913– 926.

ALMUS, M. & CZARNITZKI, D. (2003). The effects of public R&D subsidies on firms' innovation activities: the case of Eastern Germany. *Journal of Business & Economic Statistics*, 21(2), 226-236.

AGENCIA NACIONAL DE INVESTIGACIÓN E INNOVACIÓN, ANII. (2016). *Encuesta de actividades de innovación en la industria manufacturera y servicios seleccionados 2013-2015.* Montevideo: ANII.

AGENCIA NACIONAL DE INVESTIGACIÓN E INNOVACIÓN, ANII. (2015). *Encuesta de actividades de innovación en la industria manufacturera y servicios seleccionados 2010-2012.* Montevideo: ANII.

AGENCIA NACIONAL DE INVESTIGACIÓN E INNOVACIÓN, ANII. (2010). *II Encuesta de actividades de innovación en servicios 2007-2009.* Montevideo: ANII.

ARROW, K. (1962). Economic welfare and the allocation of resources for invention. In Nelson, R. R., (ed), *The rate and direction of inventive activity*, (pp. 609-626). New Jersey: Princeton University.

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.

BESANKO, D., TONG, J. & WU, J. J. (2018). Subsidizing research programs with "if" and "when" uncertainty in the face of severe informational constraints. *The RAND Journal of Economics*, 49(2), 285–310.

BLOOM, N., DRACA, M. & VAN REENEN, J. (2016). Trade induced technical change?: the impact of Chinese imports on innovation, it and productivity. *The Review of Economic Studies*, 83(1), 87–117.

BRONZINI, R. & PISELLI, P. (2016). The impact of R&D subsidies on firm innovation. *Research policy*, 45(2), 442-457.

BUKSTEIN, D., HERNÁNDEZ, E. & USHER, X. (2015). *Impacto de los instrumentos de promoción de la innovación empresarial. (BID Working Paper nº431*). Washington DC: BID.

BUSOM, PIQUER, I., CORCHUELO MARTÍNEZ-AZÚA, B. & MARTÍNEZ ROS, E. (2015). *Dynamics of firm participation in R&D tax credit and subsidy programs*. (*UAB Working Paper nº 3*). Barcelona: Universidad Autónoma de Barcelona.

CHAMBERLAIN, G. (1984). Panel data. In Griliches, Z. & Intriligator, M. (Eds.). *Handbook of Econometrics*, (pp. 1247-1318). North Holland: Elsevier.

CIRERA, X. & MALONEY, W. F. (2017). *The innovation paradox: developing-country capabilities and the unrealized promise of technological catch-up*. Washington D.C: World Bank.

COHEN, W. (1995). Empirical studies of innovative activity. In Stoneman, N. (ed.), *Handbook of the economics of innovation and technology*, (pp. 182-264). Oxford: Blackwell.

DAVID, P. A.; HALL, B. H. & TOOLE, A. A. (2000). Is public R&D a complement or substitute for private R&D?: a review of the econometric evidence. *Research Policy*, 29 (4-5), 497–529.

DE ELEJALDE, R., PONCE, C. & ROLDÁN, F. (2018). *Innovation and competition.* (ORT Working paper nº116). Montevideo: Universidad ORT Uruguay.

DIMOS, C. & PUGH, G. (2016). The effectiveness of R&D subsidies: a meta-regression analysis of the evaluation literature. *Research Policy*, 45(4), 797-815.

DUMONT, M. (2017). Assessing the policy mix of public support to business R&D. *Research Policy*, 46(10), 1851–1862.

GELABERT, L., FOSFURI, A. & TRIBÓ, J. A. (2009). Does the effect of public support for R&D depend on the degree of appropriability? *The Journal of Industrial Economics*, 57(4), 736–767.

GILBERT, R. (2006). Looking for Mr. Schumpeter: where are we in the competition–innovation debate? Innovation policy and the economy. In Jaffe, A. B., Lerner, J. & Stern, S. (Eds), *Innovation policy and the economy*, (pp. 159-215). Cambridge, MA: National Bureau of Economic Research.

GREENE, W. H. (2004). *Interpreting estimated parameters and measuring individual heterogeneity in random coefficient models*. (*SSB Working Paper EC-04-08*). New York: Stern School of Business.

GUELLEC, D. & VAN POTTELSBERGHE DE LA POTTERIE, B. (2003). The impact of public R&D expenditure on business R&D. *Economics of Innovation and New Technology*, 12(3), 225–243.

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.

HAEGELAND, T. & MØEN, J. (2007). *Input additionality in the Norwegian R&D tax credit scheme*. Reports 2007/47, Statistics Norway. Recuperado de https://www.ssb.no/a/publikasjoner/pdf/rapp_200747/rapp_200747.pdf

HALL, B. H. & LERNER, J. (2010). The financing of R&D and innovation. In Hall, B. H. & Rosenberg, N. (Eds.). *Handbook of the Economics of Innovation*, vol.1, (pp. 609-639). North Holland: Elsevier.

HALL, B. & VAN REENEN, J. (2000). How effective are fiscal incentives for R&D?: a review of the evidence. *Research Policy*, 29(4-5), 449–469.

HECKMAN, J. J. (1979). Sample selection bias as a specification error. *Econometrica*, 47(1), 153-161.

HOLMES, T. J., LEVINE, D. K. & SCHMITZ, J. A. (2012). Monopoly and the incentive to innovate when adoption involves switchover disruptions. *American Economic Journal: Microeconomics*, 4(3), 1–33.

HUERGO, E. & MORENO, L. (2017). Subsidies or loans?: evaluating the impact of R&D support programs. *Research Policy*, 46(7), 1198-1214.

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.

INTERNATIONAL MONETARY FOUD. (2019). The rise of corporate market power and its macroeconomic effects. In IMF (Ed). *World Economic Outlook: growth slowdown, precarious recovery*, (pp.55-76). Washington, D.C: IMF.

KLETTE, T. J. & MOEN, J. (1999), From growth theory to technology policy – coordination problems in theory and practice. *Nordic Journal of Political Economy*, 25(1), 53-74.

LACH, S. (2002). Do R&D subsidies stimulate or displace private R&D?: evidence from Israel. *The Journal of Industrial Economics*, 50(4), 369-390.

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.

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

NEYMAN, J. & SCOTT, E. (1948). Consistent estimates based on partially consistent Observations. *Econometrica*, 16(1), 1-32.

SCHUMPETER, J. (1942). *Capitalism, socialism, and democracy*. New York: Harper & Row.

SOLOW, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, 70(1), 65-94.

THE WORLD BANK. World Bank National Accounts Data Files. Recuperado de: https://data.worldbank.org/

WALLSTEN, S. J. (2000). The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research program. *The RAND Journal of Economics*, 31(1), 82-100.

WOOLDRIDGE, J. M. (2002). *Econometric analysis of cross-section and panel data*. (2nd ed.). Cambridge, MA: MIT.

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.

TABLES

TABLE 1.a

Summary Statistics. All firms

	Manufacturing Sectors (N=6285)				Services Sectors (N=8545)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
INNEFFORT	9.094	119	0	5040	4.93	81.90	0	5110
D_INNEFFORT	0.35	0.48	0	1	0.30	0.4	0	1
PUBSUPPREV	0.03	0.06	0	0.29	0.02	0.04	0	0.19
SECPUBSUP	0.01	0.02	0	0.66	0.01	0.02	0	0.16
TECHGAP	0.63	0.32	0	1.	0.72	0.30	0	1
D_OBSTRETURN	0.61	0.49	0	1	0.46	0.50	0	1
COMPETITION	0.70	0.23	0	0.95	0.76	0.21	0	0.97
EXPSHARE	16.06	18.37	0	100	6.78	10.36	0	100
AGE	28.02	20.37	0	144	20.42	19.22	0	162
EMPLOYEES	93.45	202.50	1	3035	171.20	625.61	1	11045

Note: Innovation expenditures are expressed in millions of Uruguayan pesos (at constant values of 2017).

TABLE 1.b

Summary Statistics. Persistent innovators

	Manufacturing Sectors (N=856)				Services Sectors (N=1,041)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
INNEFFORT	50.10	313	3,089.18	5,040	21.30	170	2.29	5,110
PUBSUPPREV	0.04	0.07	0	0.26	0.03	0.05	0	0.19
D_PUBSUP	0.32	0.47	0	1	0.16	0.37	0	1
SECPUBSUP	0.01	0.04	0	0.66	0.01	0.02	0	0.15
TECHGAP	0.54	0.34	0	1	0.73	0.30	0	1
D_OBSTRETURN	0.68	0.47	0	1	0.55	0.50	0	1
COMPETITION	0.67	0.25	0	0.95	0.74	0.23	0	0.97
EXPSHARE	18.13	20.08	0	100	11.28	28.13	0	100
AGE	32.74	23.73	0	143	26.88	26.83	0	162
EMPLOYEES	181.12	323.81	3	2,927	456.91	1280.7	2	10,065

Note: Innovation expenditures are expressed in millions of Uruguayan pesos (at constant values of 2017).

Table 2

Determinants of Innovation Expenditures

VARIABLES	Manufacturing Firms TOBIT-FE Marginal Effects (1)	Service Firms TOBIT-FE Marginal Effects (2)
PUBSUPPREV	-4.582	-12.792
	(7.176)	(10.779)
D_PUBSUP	9.873***	10.890***
	(0.903)	(1.216)
SECPUBSUP	0.447	31.820**
	(10.971)	(15.632)
TECHGAP	-4.663***	-2.762*
	(1.504)	(1.471)
D_OBSTRETURN	2.564***	-0.491
	(0.583)	(0.565)
COMPETITION	15.966*	5.310
	(9.519)	(11.171)
COMPETITION^2	-16.720*	-2.975
	(9.256)	(9.457)
EXPSHARE	-0.014	0.029***
	(0.008)	(0.010)
AGE	0.685	-0.170
	(2.533)	(2.073)
AGE^2	-0.342	0.374
	(0.491)	(0.470)
EMPLOYEES	2.259	6.861***
	(2.273)	(1.773)
EMPLOYEES^2	0.229	-0.655***
	(0.294)	(0.212)
Observations	6,249	8,383
Firm, sector, and year FE	YES	YES
F(p,q)		
Uncensored obs.	2,180	2,520
Censored obs.	4,069	5,863

Notes: columns (1) and (2) report the marginal effects of the Tobit models with firm fixed effects. Although not reported, all the specifications include the firm averages of all independent variables as additional regressors. These terms are included in the specifications to model firm fixed effects, as explained in Section 3. All specifications include year and sector fixed effects. Standard errors, in parentheses, are clustered by firm, and so robust to heteroscedasticity and autocorrelation. *** p<0.01, ** p<0.05, * p<0.1

Table 3

Determinants of Innovation Expenditures for Persistent Innovators

	Manufacturing Sectors		Service Sectors	
	Heckman first stage PROBIT	Heckman second stage OLS-FE	Heckman first stage PROBIT	Heckman second stage OLS-FE
	(1)	(2)	(3)	(4)
PUBSUPPREV	0.329***	7.265*	0.572***	17.138***
	(0.076)	(3.729)	(0.085)	(4.593)
D_PUBSUP	0.128***	2.537**	0.096***	3.031***
	(0.010)	(1.290)	(0.012)	(0.805)
SECPUBSUP	0.316*	7.306***	0.445**	13.425***
	(0.177)	(2.531)	(0.183)	(5.000)
TECHGAP	-0.075***	-1.458*	0.031***	0.863**
	(0.013)	(0.849)	(0.012)	(0.391)
D_OBSTRETURN	0.034***	0.597	0.039***	1.268***
	(0.009)	(0.366)	(0.007)	(0.346)
COMPETITION	0.101	8.435***	-0.195***	-6.788**
	(0.071)	(2.799)	(0.065)	(2.645)
COMPETITION^2	-0.198***	-8.434**	0.065	2.750
	(0.063)	(3.335)	(0.054)	(1.709)
EXPSHARE	-0.000	0.012	0.001***	0.030***
	(0.000)	(0.007)	(0.000)	(0.009)
AGE	-0.008	2.291***	-0.030*	-0.200
	(0.024)	(0.792)	(0.017)	(0.622)
AGE^2	-0.001	-0.438***	0.009***	0.337**
	(0.004)	(0.138)	(0.003)	(0.154)
EMPLOYEES	0.074***	1.776	0.042***	1.489***
	(0.017)	(1.497)	(0.010)	(0.563)
EMPLOYEES^2	-0.003	0.070	-0.001	0.015
	(0.002)	(0.142)	(0.001)	(0.039)
Inv. Mills ratio		5.050**		7.512***
		(2.570)		(1.950)
Observations	6,249	856	8,383	1,039
Log-likelihood				
R-squared		27.68%		19.21%

Notes: Columns (1) and (3) report first-stage estimates of the Heckman selection model for manufacturing and services firms, respectively, which consist of a probit model for the likelihood of being a persistent innovator. Columns (2) and (4) report second-stage estimates of the Heckman selection model for manufacturing and services firms, respectively, which consist of a fixed-effects OLS regression of the logarithm of total innovation expenditures on firm and sector level predictors, including the inverse Mills ratio. ***p<0.01, ** indicates p<0.05 and * indicates p<0.1.

Table 4

Interaction Effects of Public Support Prevalence and Technological Gap for Persistent Innovators

	Manufacturing Sectors		Service Sectors	
	Heckman first stage PROBIT	Heckman second stage OLS-FE	Heckman first stage PROBIT	Heckman second stage OLS-FE
	(1)	(2)	(3)	(4)
PUBSUPPREV	3.243***	14.924**	7.125***	32.173***
	(0.927)	(6.682)	(1.352)	(11.545)
TECHGAP	-0.339***	-1.401*	0.264***	1.145**
	(0.076)	(0.751)	(0.074)	(0.550)
TECHGAPxPUBSUPREV	-2.322*	-10.638*	-5.229***	-22.390**
	(1.299)	(5.712)	(1.692)	(9.590)
Marginal Effects				
PUBSUPPREV	0.363***	9.216**	0.591***	15.730***
	(0.078)	(4.104)	(0.085)	(5.047)
TECHGAP	-0.080***	-1.817**	0.024*	0.412
	(0.013)	(0.899)	(0.012)	(0.336)
Observations	6,249	856	8,383	1,039

Notes: Columns (1) and (3) report first-stage estimates of the Heckman selection model for manufacturing and services firms, respectively, which consist of a probit model for the likelihood of being a persistent innovator. Columns (2) and (4) report second-stage estimates of the Heckman selection model for manufacturing and services firms, respectively, which consist of a fixed-effects OLS regression of the logarithm of total innovation expenditures on firm and sector level predictors, including the inverse Mills ratio. ***p<0.01, ** indicates p<0.05 and * indicates p<0.1.

Table 5

Interaction Effects of Public Support Prevalence and Export Intensity for Persistent Innovators

	Manufacturing Sectors		Service Sectors	
	Heckman first stage PROBIT	Heckman second stage OLS-FE	Heckman first stage PROBIT	Heckman second stage OLS-FE
	(1)	(2)	(3)	(4)
PUBSUPPREV	2.448***	13.786***	3.520***	19.458***
	(0.469)	(5.183)	(0.537)	(5.042)
EXPSHARE	0.001	0.025***	0.006***	0.033***
	(0.001)	(0.008)	(0.001)	(0.009)
EXPSHARE x PUBSUPREV	-0.033***	-0.270***	-0.017	-0.140***
	(0.012)	(0.078)	(0.013)	(0.053)
Marginal Effects				
PUBSUPPREV	0.333***	7.844**	0.601***	17.875***
	(0.076)	(3.706)	(0.088)	(4.721)
EXPSHARE	-0.000	0.014*	0.001***	0.029***
	(0.000)	(0.008)	(0.000)	(0.009)
Observations	6,249	856	8,383	1,039

Notes: Columns (1) and (3) report first stage estimates of the Heckman selection model for manufacturing and services firms, respectively, which consist of a probit model for the likelihood of being a persistent innovator. Columns (2) and (4) report second-stage estimates of the Heckman selection model for manufacturing and services firms, respectively, which consist of a fixed-effects OLS regression of the logarithm of total innovation expenditures on firm and sector level predictors, including the inverse Mills ratio. ***p<0.01, ** indicates p<0.05 and * indicates p<0.1.

Table 6

Coefficient estimates of *PUBSUPPREV* for different types of firms and categories of investment in innovation.

	Manufacturing Sectors		Service Sectors	
	All firms	Persistent	All firms	Persistent
Dependent Variable	(1)	(2)	(3)	(4)
Capital Goods	-7.325	59.387***	-24.401	40.518**
	(10.300)	(16.587)	(21.128)	(16.755)
R & D	7.621	-10.687	-22.707	48.614***
	(11.953)	(11.346)	(18.017)	(14.690)
Other Categories	-6.202	-16.678	-7.235	6.604
	(8.580)	(12.812)	(11.707)	(13.783)

Notes: Each row of this table reports the coefficient estimates of *PUBSUPPREV* for three alternative dependent variables corresponding to the different categories of innovation expenditures (expenditures on Capital Goods, R&D, and Other Categories). As our database does not allow us to disentangle which portion of funds invested in each category corresponds to private or public innovation efforts, the dependent variables reflect total expenditures instead of private expenditures as in Tables 2 to 5, which use total private innovation expenditures as the dependent variable (*INNEFFORT*). Each column corresponds to one of the four samples analyzed.

Appendix A

TABLE A.1

Summary Statistics. Non-Persistent innovators

	Manufacturing Sectors (N=5,429)				Services Sectors (N=7,504)			
	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
INNEFFORT	4.66	31.4	0	1,270	5.52	82.2	0	3,690
PUBSUPPREV	0.03	0.05	0	0.29	0.01	0.03	0	0.19
D_PUBSUP	0.16	0.37	0	1	0.08	0.28	0	1
SECPUBSUP	0.01	0.02	0	0.21	0.00	0.02	0	0.16
TECHGAP	0.64	0.31	0	1	0.72	0.30	0	1
D_OBSTRETURN	0.60	0.49	0	1	0.45	0.50	0	1
COMPETITION	0.71	0.23	0	0.95	0.76	0.21	0	0.97
EXPSHARE	15.12	31.16	0	100	6.15	20.63	0	100
AGE	27.28	19.68	0	144	19.52	17.72	0	158
EMPLOYEES	79.59	171.	1	3,035	131.22	451.53	1	11,045

Note: Innovation expenditures (*INNEFFORT*) are expressed in millions of Uruguayan pesos (at constant values of 2017). *INNEFFORT* and D_PUBSUP are computed using information among firms that report positive innovation expenditures in at least one year of the analyzed period (but not every year; otherwise, they would be classified as persistent innovators).

TABLE A.2

Determinants of Innovation Expenditures for Non-Persistent Innovators

VARIABLES	Manufacturing firms TOBIT-FE Marginal Effects (1)	Service Firms TOBIT-FE Marginal Effects (2)
PUBSUPPREV	-8.382	-15.016
	(9.900)	(15.631)
D_PUBSUP	15.675***	16.144***
	(1.299)	(1.711)
SECPUBSUP	28.671	46.908**
	(20.121)	(20.626)
TECHGAP	-5.862***	-3.037
	(2.111)	(2.082)
D_OBSTRETURN	2.550***	-0.937
	(0.794)	(0.787)
	(1.176)	(1.187)
COMPETITION	15.733	3.709
	(13.105)	(15.621)
COMPETITION^2	-14.601	-0.553
	(12.643)	(13.354)
EXPSHARE	-0.021*	0.022
	(0.012)	(0.015)
AGE	1.668	1.260
	(3.372)	(2.789)
AGE^2	-0.416	0.356
	(0.669)	(0.625)
EMPLOYEES	2.350	10.374***
	(2.911)	(2.582)
EMPLOYEES^2	0.349	-1.049***
	(0.378)	(0.324)
Observations	5,393	7,344
F(p,q)		
Uncensored obs.	1,324	1,481
Censored obs.	4,069	5,863

Notes: Columns (1) and (2) report the marginal effects of the Tobit models with firm fixed effects. Although not reported, all the specifications include firm averages of all the independent variables as additional regressors. These terms are included in the specifications to model firm fixed effects, as explained in section 3. All specifications include year and sector fixed effects. Standard errors, in parentheses, are clustered by firm, and so robust to heteroscedasticity and autocorrelation. *** p<0.01, ** p<0.05, and * p<0.1.

Appendix B

Sectoral Public Support Prevalence Variable

We compute a measure of sectoral public support prevalence by considering two relevant dimensions that describe the allocation of public support within a sector: (i) the share of firms receiving public support, and (ii) the distribution of public funds for innovation among supported firms within the sector. We proceed as follows.

We compute the Hirschman-Herfindahl Index of innovation expenditures supported by the public sector:

$$HHI_{jt}^{PUBSUP} = \sum_{i\epsilon j}\left(\frac{PUBSUP_{ijt}}{PUBSUP_{jt}}\right)^2 \in [0,1],$$

where $PUBSUP_{ijt}$ is the amount of public support received by firm *i* in sector *j* at time *t*, and $PUBSUP_{jt}$ is the amount of public support received in sector *j* at time *t*.

Let us note that HHI_{jt}^{PUBSUP} refers to the distribution of public support among the firms that receive it. Let us denote by r_{jt} the number of firms that receive public support in sector *j* at time *t*, and by n_{jt} the total number of firms in sector *j* at time *t*.

Three remarks are in order.

Remark 1. When public support has minimum concentration, then $HHI_{jt}^{PUBSUP} = \frac{1}{r_{jt}}$.

Proof. When public support has minimum concentration, each supported firm receives $\frac{1}{r_{jt}}$. Then,

$$HHI_{jt}^{PUBSUP} = \sum_{i\epsilon j}\left(\frac{PUBSUP_{ijt}}{PUBSUP_{jt}}\right)^2$$

$$HHI_{jt}^{PUBSUP} = \sum_{i\epsilon j}\left(\frac{1}{r_{jt}}\right)^2$$

$$HHI_{jt}^{PUBSUP} = \left(\frac{1}{r_{jt}}\right) \quad \blacksquare$$

Remark 2. When public support has maximum concentration, then $HHI_{jt}^{PUBSUP} = 1$.

Proof. When public support has maximum concentration, only one firm receives all public support in sector *j* at time *t*. Then, $HHI_{jt}^{PUBSUP} = 1$. ■

Remark 3. HHI_{jt}^{PUBSUP} can be written as

$$HHI_{jt}^{PUBSUP} = \left(\frac{1}{r_{jt}} + r_{jt}\sigma_{jt}^2\right) \in [0,1],$$

where σ_{jt}^2 is the variance of public support among firms in sector *j* at time *t*.

Proof . Let us denote by $s_{ijt} = \frac{PUBSUP_{ijt}}{PUBSUP_{jt}}$. By using the variance definition,

$$\sigma_{jt}^2 = E\left({s_{ijt}}^2\right) - \left[E\left(s_{ijt}\right)\right]^2$$

$$\sigma_{jt}^2 = \frac{\sum_{i\epsilon j}\left({s_{ijt}}^2\right)}{r_{jt}} - \frac{\left(\sum_{i\epsilon j} s_{ijt}\right)^2}{r_{jt}^2}$$

$$\sigma_{jt}^2 = \frac{HHI_{jt}^{PUBSUP}}{r_{jt}} - \frac{1}{r_{jt}^2}$$

Then,

$$HHI_{jt}^{PUBSUP}\left(\sigma_{jt}^2, r_{jt}\right) = \left(\frac{1}{r_{jt}} + r_{jt}\sigma_{jt}^2\right). ■$$

Thus the Hirschman-Herfindahl index is a function of σ_{jt}^2 and r_{jt}. It is straightforward to see that as the variance increases, the concentration measured by HHI_{jt}^{PUBSUP} increases.

We define dispersion as:

$$Dispersion_{jt} = (1 - HHI_{jt}^{PUBSUP}) \in [0,1]$$

By replacing HHI_{jt}^{PUBSUP}

$$Dispersion_{jt}\left(\sigma_{jt}^2, r_{jt}\right) = (1 - \frac{1}{r_{jt}} - r_{jt}\sigma_{jt}^2) \in [0,1]$$

Corollary 1. As the variance of public support in a particular sector increases, the $Dispersion_{jt}$ in that sector decreases.

Proof. It follows by taking partial derivative from $Dispersion_{jt}(\sigma_{jt}^2, r_{jt})$ with respect to σ_{jt}^2. ■

Since this variable's objective is to proxy how prevalent public support is within sectors, we combined the dispersion variable that accounts for the distribution of public support within supported firms with information regarding the share of firms receiving public support for innovation within the sector. Therefore, the final measure of sectoral public support prevalence weights the dispersion variable by the share of supported firms within the sector and is defined as:

$$PUBSUPPREV_{jt} = Dispersion_{jt}\ x\ \frac{r_{jt}}{n_{jt}}$$

$$PUBSUPPREV_{jt}\ (\sigma_{jt}^2, r_{jt}, n_{jt}) = (1 - HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2))\ x\ \frac{r_{jt}}{n_{jt}}$$

Thus the *PUBSUPPREV* variable is a function of σ_{jt}^2, r_{jt} and n_{jt}.

Therefore, we are able to state the following.

Claim 1. Given the number of firms that receive public support and the number of firms in a particular sector, as the variance of public support in that sector increases, the prevalence of public support ($PUBSUPPREV_{jt}$) decreases.

Proof

$$\frac{\partial PUBSUPPREV_{jt}\ (\sigma_{jt}^2, r_{jt}, n_{jt})}{\partial \sigma_{jt}^2} = -\frac{\partial HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2)}{\partial \sigma_{jt}^2}\ x\ \frac{r_{jt}}{n_{jt}}$$

Using Remark 3:

$$\frac{\partial PUBSUPPREV_{jt}\ (\sigma_{jt}^2, r_{jt}, n_{jt})}{\partial \sigma_{jt}^2} = -\frac{r_{jt}^2}{n_{jt}} < 0 ■$$

Claim 2. Given the number of firms that receive public support in a sector and given a level of concentration of that public support within it, as the total number of firms in the sector increases, the prevalence of public support ($PUBSUPPREV_{jt}$) decreases.

Proof. We derive the expression for $PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)$with respect to n_{jt}, and we get

$$\frac{\partial PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)}{\partial n_{jt}} = -\frac{(1 - HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2))r_{jt}}{n_{jt}^2} < 0$$

Claim 3. Given the number of firms in a sector and the level of concentration of public support within it, as the number of firms that receive public support increases, the prevalence of public support ($PUBSUPPREV_{jt}$) increases.

Proof. We derive the expression for $PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)$with respect to r_{jt}, and we get

$$\frac{\partial PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)}{\partial r_{jt}} = -\frac{\partial HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2)}{\partial r_{jt}}\ x\ \frac{r_{jt}}{n_{jt}} + (1 - HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2))\ x\frac{1}{n_{jt}}$$

Given that $\frac{\partial HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2)}{\partial r_{jt}} = -\frac{1}{r_{jt}^2} + \sigma_{jt}^2$, then

$$\frac{\partial PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)}{\partial r_{jt}} = -\left(-\frac{1}{r_{jt}^2} + \sigma_{jt}^2\right)\ x\ \frac{r_{jt}}{n_{jt}} + (1 - HHI_{jt}^{PUBSUP}(r_{jt}, \sigma_{jt}^2))\ x\frac{1}{n_{jt}}$$

$$\frac{\partial PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)}{\partial r_{jt}} = \left(\frac{1}{r_{jt}} - r_{jt}\sigma_{jt}^2\right)\ x\ \frac{1}{n_{jt}} + (1 - HHI_{jt}^{PUBSUP})\ x\frac{1}{n_{jt}}$$

By using Remark 3,

$$\frac{\partial PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)}{\partial r_{jt}} = \left(\frac{1}{r_{jt}} - r_{jt}\sigma_{jt}^2\right) x \frac{1}{n_{jt}} + (1 - \frac{1}{r_{jt}} - r_{jt}\sigma_{jt}^2)\ x\frac{1}{n_{jt}}$$

$$\frac{\partial PUBSUPPREV_{jt}\left(\sigma_{jt}^2, r_{jt}, n_{jt}\right)}{\partial r_{jt}} = \left(1 - 2r_{jt}\sigma_{jt}^2\right) x\frac{1}{n_{jt}}$$

The last expression is positive as long as $r_{jt}\sigma_{jt}^2 < \frac{1}{2}$.

By recalling that $Dispersion_{jt} = (1 - \frac{1}{r_{jt}} - r_{jt}\sigma_{jt}^2)$, then $r_{jt}\sigma_{jt}^2$ is always less than or equal to $\left(1 - \frac{1}{r_{jt}}\right)$ since $Dispersion\ \epsilon[0,1]$.

Therefore for $r_{jt} > 2$, the condition $r_{jt}\sigma_{jt}^2 < \frac{1}{2}$ always meets.

Accordingly, we can state the following two Lemmas.

Lemma 1. The prevalence of public support in sector *j* at time *t* increases as the dispersion in public support allocation within supported firms increases.

Proof. It follows from Corollary 1 and Claim 1.

Lemma 2. The prevalence of public support in sector *j* at time *t* increases as the number of firms receiving public support increases, as long as the number of recipients is greater than 2.

Proof. It follows from Claim 3.