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The role of public procurement as innovation lever: evidence from Italian manufacturing firms

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Abstract

The study focuses on the impact exerted on private R&D expenditures by regular and innovative public procurement when taken in combination or insolation with supply-push measures. The econometric analysis relies on a pulled sample of 4,206 Italian manufacturing firms observed between 2010-2014. The empirical exercise confirms previous evidences on the relevance of technology-push instruments in sustaining firms' innovativeness. On the contrary, the ability of public procurement activities in shaping innovative investments is found to depend on a number of instances related to: i) the adoption of contemporaneous supply side measures; ii) the inclusion of innovative demand in procurement contracts. The analysis provides important suggestions with respect to the potential effectiveness of demand-side tools when implemented in weak administrative and innovation systems, as in the Italian case. Moreover, it is shown that the design of the policy mix matters, and its effectiveness improves when demand-side and supply-side instruments are jointly implemented.

Keywords: *Demand-pull policies, Public Procurement, Policy-mix, Non-parametric analysis.*
JEL codes: H570, O250, O380

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Introduction

The role of *demand-side* policies as enabler and source of innovation is gaining increasing momentum from both policy and academic perspectives (Edler and Georghiou, 2007; Izsak and Edler 2011; Uyarra 2013).

The main rationale beyond the use of this class of measures basically originates from the opportunity of lowering market uncertainty on innovation outcomes through public sector's purchasing power, namely public procurement (PP). By demanding innovative products or/and enlarging the market for the existing ones, PP could potentially provide the productive sector with new or additional amount of market demand, thus allowing to successfully finalize the commercialization process of new technologies.

To date, the research effort devoted at investigating the link between procurement and innovation has been mostly developed through case-studies, mainly concentrated on Northern Europe countries, where findings generally show a positive relation between procurement activities and innovative performances (see for example Edquist and Hommen, 2000; Rolfstam, 2009; Uyarra and Flanagan, 2010; Flanagan et al., 2011; Brammer and Walker, 2011).

However, countries largely differ in their administrative capacity and in the ability to manage pro-innovation procurement activities (Lember et a., 2015; Thijs et al., 2018). In this respect, Italy represents a relevant and largely unexplored case to be analyzed in order to evaluate the efficacy of demand-side/procurement policies in stimulating innovative activities when the institutional and administrative framework is characterized by low level performances. This paper, building on a growing empirical literature (Aschhoff and Sofka, 2009; Slavtchev and Wiederhold, 2011; 2016; Appelt and Galindo-Rueda, 2016; Guerzoni and Raiteri, 2015; Antonelli and Gehringer, 2015; Ghisetti 2017; Raiteri, 2018; Crespi and Guarascio, 2018; Florio et al., 2018; Czarnitzki et al., 2018; Divella and Sterlacchini, 2018; Caravella at al., 2020), tries to offer a contribution in this direction by adopting a quantitative approach, instead of more diffused case study based analyses.

More specifically, the proposed analysis looks at the effects of both *regular* (RPP) and *innovation-inducing* (IPP) domestic procurement contracts, where the latter differ from the former because innovation is part of contracts' requirements. As policy target variable, we look at input additionality which is represented by the amount of private R&D investments achieved by firms. The analysis is narrowed to firms belonging to manufacturing sectors, where the bulk of R&D expenditures are mostly concentrated (David et al., 2000). More in detail, the study is realized on a pulled dataset made of 4,206 observations representing firms that have introduced, at least, one technological innovation (product or process innovation). Information is drawn from the 6th and 7th waves of the Community Innovation Survey (CIS) and the AIDA database, and covers the period 2010-2014. The exercise is built within the framework of policy evaluation studies and it is carried out through a quasi-experimental technique which allows for a better control of bias-related issues. With respect to previous literature, specific attention is devoted to the so-called "hidden effect", which it is likely to occur when the outcome of a given policy is influenced by the presence of other policies (Guerzoni and Raiteri, 2015). For this reason, the impact of public procurement is evaluated both in combination and isolation with supply-push measures (soft loans, tax deduction and grants) and a number of sensitivity tests are carried out.

The remainder of the paper is organized as it follows. Contextualizing the *demand-side* instruments within the framework of the modern policy innovation theory, Section 2 discusses the opportunities and limits of public procurement in stimulating demand-driven innovative investment, by also collecting empirical evidences on the impact of *demand-side* innovation policies on firms' innovativeness. Section 3 provides an overview of the main features of the Italian procurement system while section 4 is dedicated at defining the dataset and the econometric strategy. Finally, Section 5 reports the results and Section 6 summarizes the main insights emerging from the study, highlights the policy implications and outlines possible further research lines.

1. Background literature

The main arguments in favor of the importance of demand as an incentive for innovation come back to the seminal contributions by Schmookler (1962) and Myers and Marquis (1969) who stress the importance of demand dynamics in influencing investment in inventive activities across products and industries, by arguing that demand conditions affect the desirability and realization of inventions. In this view, the existence of expected profitability and the potential expansion of market demand represents the key stimulus for inventive activities (Mowery and Rosenberg, 1993; Kleinknecht and Verspagen, 1990). More recently, further development by evolutionary scholars, highlighted the relevance of demand conditions as a determinant of innovative performances (Andersen, 2001; Metcalfe, 2001; Saviotti and Pyka, 2004). In parallel, a flourishing new empirical literature on barriers to innovation associated with demand-related (i.e., lack of) incentives to invest in innovation (D'Este et al., 2012; Iammarino et al., 2009). Following this perspective, García-Quevedo et al. (2016) find evidence that positive expectations on the presence of adequate demand are a necessary condition to engage in innovative activities. As opposed, low levels in the expected demand for innovative solutions reflect low potential profits and returns from the investments associated with the development and commercialization of new products and processes. Seen in this vein, the perception of a lack of demand exerts a marked negative impact on both the decision to invest and on the amount of investment in R&D activities that will eventually be incorporated into the innovative goods (Piva and Vivarelli, 2007; Gallup 2011; Uyarra et al. 2014; Antonelli and Gehringer, 2015).

Such a renewed interest in the role of demand embraced also the innovation policy debate, with increasing attention paid to *demand-side* policies to foster innovation (Edler and Georghiou, 2007; Roolaht, 2010; OECD, 2011; Gheorghiou et al. 2014) and PP identified as a key instrument of innovation policy in both developed and developing countries (Uyarra and Flanagan, 2010; Filippetti and Archibugi, 2011; Edquist, 2015; Mazzucato and Kattel, 2018). In particular, the limitations of supply-push policies in ensuring the diffusion and adoption of innovative products or services within the market have been underlined by two relatively fresh streams of research. The first overcomes the concept of *market-failures policy-based* perspective, arguing that public sector funding can, and actually often does, much more than fixing market failures (Mazzucato, 2015). In this respect, by creating new products and related markets, public sector can push forward the boundaries of technologies, drive industrial renewal and structural change processes rather than just incentivizing or stabilizing existing markets or sectors (Mazzucato, 2015). The second goes beyond the conception of innovation as a linear process by adopting an "holistic" perspective (Edquist, 2014). Here, the innovation process is seen as a "system" which encompasses "all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations" (Edquist, 1997). In such an holistic view of innovation policy, instruments able to stimulate demand-driven innovative investments are claimed to be central (Edquist, 2015).

Public procurement (PP) represents the main operative tool of demand-pull policies. PP in the OCED area covers almost 30% of national government spending and accounts for a share of above 13% of GDP[1]. By consolidating and creating markets, and thus reducing uncertainty, PP provides suppliers with strong incentives for coming up with innovative solutions that allow for the upgrading of goods and services. In so doing, PP is recognized as a key driver of technological upgrading (Uyarra and Flanagan, 2010; Edquist, 2015), whether the stimulation of innovations is an explicit goal of procurement (*innovation-inducing*) or not (*regular*).

Early evidence on the link between public procurement and innovation has been provided by Lichtenberg (1988) who investigated the private R&D investment response to the US government procurement on annual 1979-84 panel data for 169 industrial firms. By distinguishing between competitive (design and technical competition, price competition) and non-competitive tenders, he found that a 1$ increase in the former (competitive procurement) induces 54 cent of additional R&D, while a 1$ increase in the latter (not competitive procurement) tends to reduce private R&D by more than 2$.

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[1] Data available at the web site https://stats.oecd.org/index.aspx?r=171728#

Similar findings are provided by Draca (2013) who exploits the analytical framework by Hall et al., (2000) to include the US military procurement spending among the demand–side factors affecting firms innovation investment decision. Looking at the period 1966-2003, the analysis shows a positive and significant impact of military procurement on both patenting activities and R&D investment, especially under the early Reagan build-up when the contribution of defense procurement to innovation accounted for 11.4% of the total change in patenting intensity and 6.5% for R&D. A more recent study by Slavtchev and Wiederhold (2016) provides a comprehensive econometric assessment of the link between the technological content of government purchases and private R&D activities for annual 1999-2009 panel data. By making use of a model of endogenous growth where the technological intensity of both procurement and industries is accounted for, the analysis suggests that each procurement dollar that the government shifts from low-tech industries to high-tech industries induces additional 0,21$ of private R&D. However, empirical evidence on the role of PP in driving innovation are rather controversial (Uyarra et al., 2014). For instance, while Florio et al. (2018) showed the efficacy of CERN PP activities in shaping innovation performances of suppliers especially if involved in structured and collaborative relationships with CERN, Czarnitzki et al. (2018) find, in the German case, that only if the innovation is required by contract (Public Procurement with Contracted Innovation) the effect on innovative turnover is positive, although limited to products and services that are merely new to the firm.

Such heterogeneity in empirical findings might be explained by the differences in ways and contexts where procuring activities are set up. Indeed, as stressed by more qualitative studies, the success of PP in spurring innovation not only relies on the ability of the productive system to exploit the innovation opportunities eventually provided by PP (Appelt and Galindo-Rueda, 2016; Divella and Sterlacchini, 2018). On the contrary, it also depends on two key elements. The first is the competence of institutions in embedding procuring activities on *innovation-enhancing* purposes (Kattel and Lember, 2010; Uyarra et al., 2014), while the other is the complementarity between public demand and other innovation policy tools (Di Stefano et al.,2012; Lember et. al 2014).

As regard the former, it generally mirrors the way whereby public entities manage PP in terms of (i) *strength* (quantity and frequency whereby products are demanded), (ii) *direction* (objectives associated with the procuring activities as, for example, environmental, climate, energy, urban development, health, transport, defense etc.), (iii) *design* (modalities) and (vi) *implementation* (procedures). In this respect, it might be argued that weaknesses or inefficiencies occurring in one, or more, dimensions of the procurement system might negatively affect the potential of PP in stimulating innovation activities. Such good, or bad, practices in dealing with resources, organizational and procedural aspects of procurement largely depend on country-specific issues (Mourão and Cantu 2014, Uyarra et al. 2014, Li et al., 2015, Rolfstam and Petersen, 2014, Cepilovs, 2013; Lember et al.,

2014) and systemic hindrances (Amann and Essig 2015; Georghiou et al. 2013; Rolfstam, 2012) that shape the conditions under that the impact of PP takes (or could potentially take) place. PP activities may if fact differ across countries, and sectors, in terms of: (i) different and often contradictory ideas about the role of public procurement, especially in regard to the trade-off between static and dynamic efficiency (Nyiri et al., 2007); (ii) different attitude of procuring authorities towards risk aversion and reluctance to change (Rolfstam 2012; Edler et al., 2015); (iii) institutional capacities, internal technological competences and coordination practices (Lember et al., 2014) that public authorities often lack (Rolfstam, 2002; Lember et al. 2015), in particular when sub-national institutions are involved (Albano and Sparro, 2010; Georghiou et al., 2014).

However, the success of PP as innovation lever not only relies on the ability of procuring entities to prevent, or even offset, flaws in procurement systems. Conversely, the effectiveness of innovation-enhancing procurement is also influenced by their interactions with other policy instruments. These embrace policy tools that, as in the case of technology-push measures, are aimed at counteracting market failures not directly linked to demand conditions (Borrás and Edquist, 2013). The main rationale for mixing demand-side policies with other policy instruments is provided by the fact that decreasing demand uncertainty *via* public demand unless dealing with other innovation-related problems (such as appropriability problems and information asymmetries) might neutralize, or even offset, the potential impact of the former on innovation outcomes. For this reason, to better enhance their effectiveness as innovation lever, procurement activities should be paralleled by complementary policy measures and, more in general, framed into a "instrument-mix context" (EC, 2009; Martin, 2016).

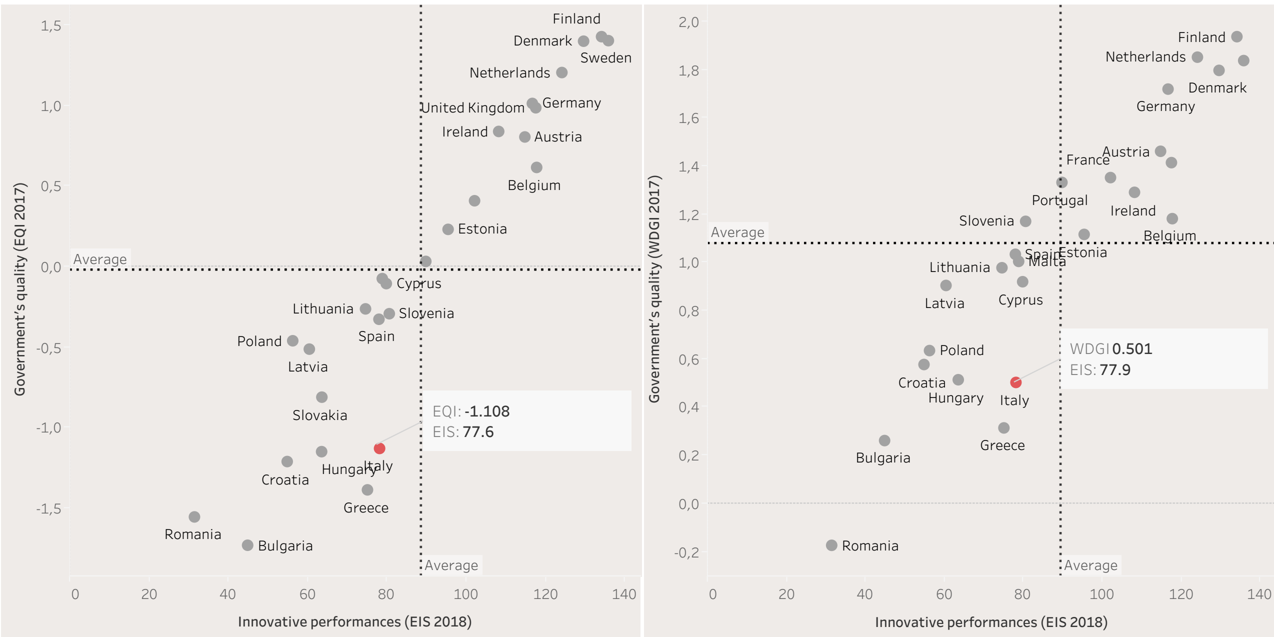
Despite the great emphasis recently attached to this issue, evaluation practices devoted at investigating the pro-innovation role of procurement in relation to other policy actions are still in their infancy. A first attempt in this direction is provided by Aschhoff and Sofka (2009), who perform a latent class tobit regression on a sample of 1.100 German firms in order to investigate the impact of public procurement, among other different policy tools such as regulation, R&D subsidies, knowledge spillover from university, on the share of turnover sourcing from the development of innovations with market novelty during the three-year period 2000-2002. Their findings suggest that both public procurement and knowledge spillovers from universities exert a positive impact on innovation, especially for small firms placed in Western Germany. Focusing on innovation inputs, Guerzoni and Raiteri (2015) enhance the evaluation technique by performing a quasi-experimental analysis on 4.992 European firms surveyed by the Innobarometer survey (2006–2008). Their findings show that firms involving in both innovative procurement contracts and tax credit programs have the highest probability of increasing R&D expenditures. In a more recent study by Stojčić et al., (2019), it is provided an attempt to assess for a sample of 41,623 firms belonging to eight Central & Eastern European countries the relationship between both public funding and public procurement for innovation and firm-level innovation output (process and product innovation) and outcome (% of turnover sourcing from new to firm and new to market products) additionality. Two key findings have emerged from their analysis. First, when public procurement is not tailored in a way that requires firms to come up with novel products and processes, the combination between the two policy channels are likely to produce weaker effects than those achieved through *push* policies alone. As opposed, when public procurement is structured in a way that specifically stimulates innovation, its combination with financial support to innovation, displays the largest positive impact.

2. *The Italian case*

The choice to concentrate the analysis on the Italian case is mainly due to some key peculiarities in the national context. For example, considering the most developed European economies, Italy records the lowest innovative and administrative performances (Figure 1). In this regard, looking at the most recent data, Italy lags behind many European countries in the annual ranking proposed by the European Innovation Scoreboard (EIS). In addition, both the European Quality of Government Index (EQI) developed by the University of Gothenburg and the government effectiveness indicator of provided by the World Bank (WDGI) [2] show that Italy's position is well below the European average. More specifically, looking at the overall government performance, Italy joins the lowest positions together with Greece, Bulgaria and Romany (Hammerschmid et al., 2017).

Figure 1. Innovative and administrative performances across EU countries

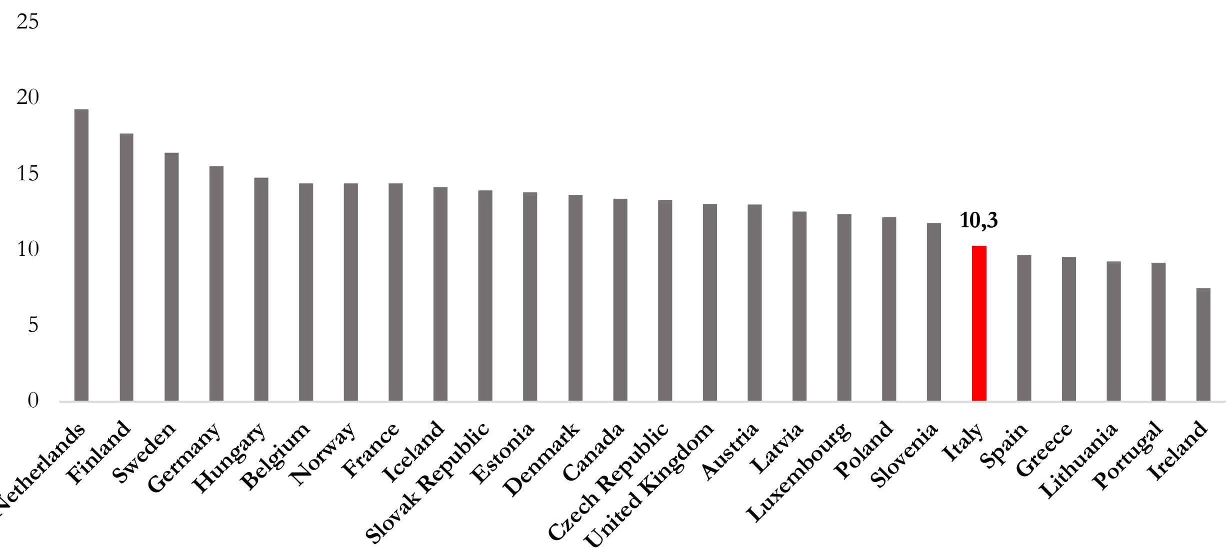
[2] For a detailed description see EC (2018)



Source: Authors' elaborations on EQI, WDGI and EIS databases

Moreover, as indicated by the results provided by the 2019 edition of Government at a Glance by OECD, among the OECD countries, Italy is placed in the last positions regarding the amount of the government procurement expenditures expressed as ratio on GDP (Figure 2).

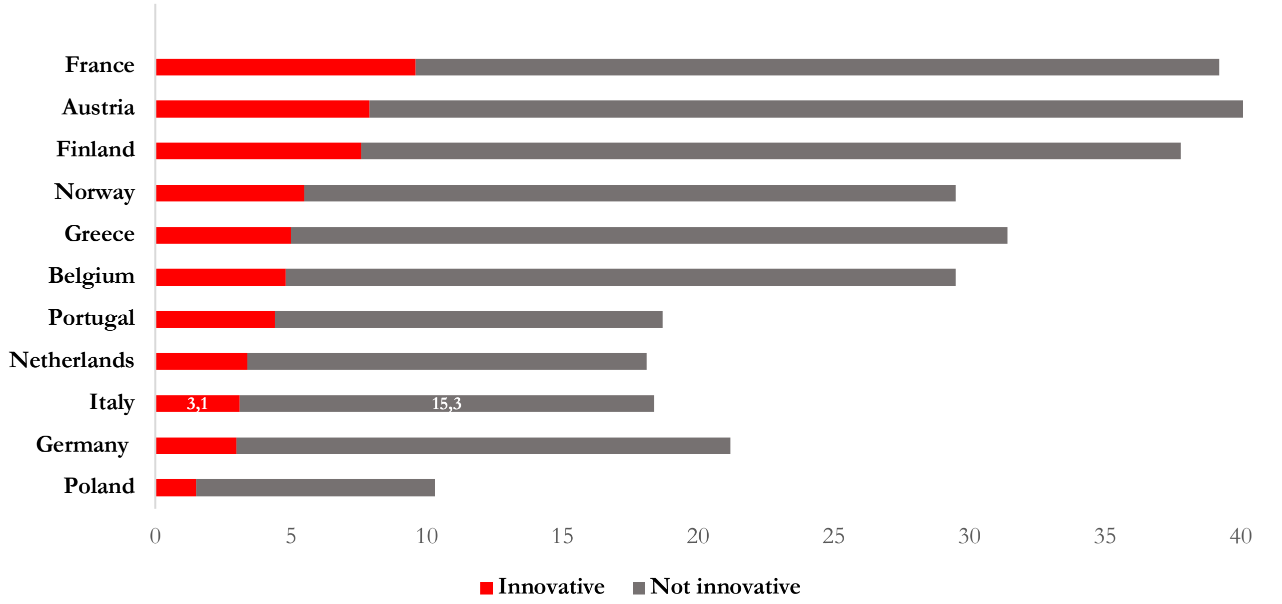
Figure 2. General government procurement as a percentage of GDP (year=2018)



Source: Authors' elaborations on OECD data

Finally, as provided by the 2010-2012 wave of the Community Innovation Survey, the use of public procurement made by the Italian public entities to sustain innovation is almost negligible (Figure 3)

Figure 3. Percentage of firms involved in procurement contracts (year 2010-2012)



Source: Authors' elaborations on Community Innovation data

Note: The percentage of innovative PP contracts is computed by considering all procurement contracts contemplating innovation as both formal (1,7%) and informal (1,4%) contract's requirement. See footnote 6 for more details.

Three main arguments can provide an explanation of this evidence. Firstly, the limited exploitation of PP innovation-related opportunities by the Italian industrial system depends on its own features, i.e. the prevalence of small and medium sized firms, the low intensity of *in-house* R&D expenditures and the low educational levels of employees (Divella and Sterlacchini, 2018). Secondly, Italian innovation and industrial policy mainly relies on supply-push policies, while demand-pull instruments play a secondary and marginal role (Lucchese et al., 2016; Nascia and La Placa, 2016; Caravella and Crespi, 2018). Finally, - as claimed by the latest EC report on the monitoring of the administrative capacity of procurement in European countries[3] - Italy suffers from a fragmented and complex legal framework which, in turn, bounds procurement procedures and limits the flexibility of contracting authorities and economic operators. Furthermore, Italian procurement practitioners lack of business experience and economics background needed to implement more complex and demanding procurement projects.

To overcome these hindrances, Italy has recently launched a season of reforms oriented to a market push and demand-driven perspective. Concerning the public purchasing of innovative goods, the Italian normative framework has been recently

[3] Available at the webpage: https://ec.europa.eu/regional_policy/sources/policy/how/improving-investment/public-procurement/study/country_profile/it.pdf

updated[4] with the introduction of new enhancing instruments as, for example, the possibility to establish a long-term innovation partnership by contracting entities for the development and subsequent purchase of new products, without separating procurement procedure from the purchase.

However, despite these efforts, the Italian procurement system still appears far from being able to exploit its innovative potential. As a matter of fact, the claims exposed by the EC report have been recently confirmed by the Italian Digital Agency (AgID), the entity in charge of diffusing new information and communication technologies in the country. AgID signals serious flaws that affect the Italian PP framework. These basically involve: (i) the insufficient expertise of the procurement entities in both acknowledging and managing the new instruments; (ii) the short-term and static-efficiency approach to PP, which is still focused on cost-saving considerations instead of innovation goals; (iii) the design of the National Frame Contracts - managed by Consip S.p.a, the Italian Public Procurement agency - aimed at the rationalization of public spending in goods and services.

The claims reported by EC and AgID show that the Italian procurement system suffers from a number of weaknesses and inefficiencies. More in general, Italy displays remarkable lags in administrative and innovative performances when compared to Northern European countries where, however, the largely documented successful use of *innovation-enhancing* procurement has been only rarely considered in relation to other innovation policy instruments.

In conclusion, by focusing on the Italian case, the present work aims to provide the following contributions. Firstly, we enrich the empirical assessment of the pro-innovation role of PP by looking at a national context, the Italian one, that deeply differs from those characterizing the most investigated countries. Secondly, we frame the empirical exercise in the context of the "innovation instrument mix", thus devoting attention to an issue largely neglected by previous empirical investigations on this topic.

More specifically, the following empirical analysis is aimed at ascertain: i) if and to what extent PP is able to stimulate private innovation activities when the administrative and institutional context is weak, as in the Italian case; ii) if and to what extent the impact of PP on private innovation activities is influenced by its interaction with other innovation policy tools.

[4] Law Decree 50/2016, Tree-year plan 2017-2019 of AgID (Digital Italy Agency), the 2018 Framework Agreement for Growth and Digital Citizenship in line with 2014 European directives (23/EU, 24/EU and 25/EU)

4. Empirical analysis

4.1 Data and Methodology

The analysis is aimed at evaluating the capacity of the Italian procurement activity to stimulate R&D-related investment which, in line with great part of previous literature, is the chosen policy target for our analysis.

Concerning PP, we adopt two distinct notions: *regular public procurement* (RPP) and *innovation-inducing public procurement* (IPP) where, in the latter, innovation activities are required in the procurement contracts. Although IPP might better suit innovation purposes by directly demanding not yet existing innovative products, RPP might enlarge market demand for innovative products, thus inducing new or additional firms' R&D investments[5] or increasing the share of innovative turnover. Moreover, this latter is certainly the most diffused way of conducting procurement because it is easier to be managed than IPP.

Operatively, to identify RPP and IPP contracts, we made use of two key questions provided by the 2012 and 2014 Community Innovation Survey (Box 1). In question 10.1 of the questionnaire, firms were asked about their involvement in procurement activities during the reference period, while in question 10.2 companies who affirmatively responded to the previous one, were also asked whether they have undertaken any innovation activities as part of the contract.

Box 1. Main questions on public procurement in the 2012 and 2014 Community Innovation Survey

10.1 "During 2010-2012 (2012-2014), did your enterprise have any procurement contracts to provide goods or services for:

(a) Domestic public sector organisations;
(b) Foreign public sector organisations.

10.2 "Did your enterprise undertake any innovation activities as part of a procurement contract to provide goods or services to a public sector organisation?

-Yes, and innovation required as part of the contract
- Yes, but innovation not required as part of the contract
- No

[5] In the most commonly used definition of IPP', innovation activities might be based (or not) on "additional or new development work" as, for example, R&D efforts. In this case, we refer to "indirect public procurement of R&D", which is the one we attempt to detect in the analysis. So that, "indirect public procurement of R&D" deeply differs from "direct R&D procurement" (or "pre-commercial procurement") where, on the contrary, the public sector pays for R&D services since as R&D is the actual object of procurement (on this point see Petrella, 2013).

Accordingly, we identify our focus variables as it follows. RPP is built by assigning value equal to 1 if a company has claimed to be involved in a domestic procurement contract without undertaking innovation activities as part of procurement contracts. Similarly, IPP is shaped by attaching value 1 if a company involved in a domestic procurement contract claimed to undertake innovation activities as part of a domestic procurement contract[6]. The empirical analysis is based on firm-level data drawn from the 6th and 7th waves of the Italian Community Innovation Survey referring to the three-year periods 2010-2012 and 2012-2014, respectively. The survey, developed by Eurostat according to the Oslo Manual and collected by Istat (Italian National Statistical Institute) every two-year, includes a representative sample of firms with at least 10 employees identified by a stratified random sampling, plus the whole population of firms with more than 249 employees. The CIS dataset has been integrated with balance-sheet data extracted from the AIDA-Bureau VanDijk database which provides information on firms' financial structure. After dropping non-innovative firms (for which relevant information on policies is missing), those operating in service sectors, and cleaning for missing information, the final pooled sample consists of 4,206 observations[7].

As stated before, the treatment variables referring to RPP and IPP and private R&D investment that represents the outcome variable[8].

The empirical strategy consists in a counter-factual analysis with the aim to "recreate" what would have happened to the same treated firm if it had not received the treatment.

Formally:

$$ATT\ (ATET) = E\left(Y_i^1 - Y_i^O \middle| T = 1\right) \quad (1)$$

where Y^1 and Y^0represent the outcome variable of the treated unit *i* with and without treatment, respectively.

In other words, the basic idea beyond this method is to compare the same unit in both states of the world, i.e. with or without treatment, by creating a hypothetical situation where the treated unit is untreated and then testing if there are significant differences in the mean of the variable of interest. Being the "counterfactual" situation not directly observable for the same unit, a "twin" unit is used as control. In this case, the average treatment effect on treated firms (ATET) is estimated by comparing differences on the

[6] To identify IPP in CIS questions, we rely on innovation activities undertaken by firms *"as part of procurement contract"*, thus regardless innovation is intended as "formal" requirement or not. This point is deeply discussed by Edquist (2015) who argues that, according to the different forms whereby IPP might be set up, contracted innovations might be intended both in terms of "formal" or "informal" requirement to innovate.

[7] 451 innovative manufacturing firms have been dropped from the analysis because of missing balance sheet data.

mean of the target variable between the groups of treated and control, which are assumed to be identical to each other, except for the treatment.

This procedure works if, and only if, the two groups are perfectly randomized, which means that the probability of taking part to a policy program must be not correlated with individual characteristics of the firm. Formally:

$$Y_i^1;\ Y_i^0 \perp T \tag{2}$$

Such assumption rarely holds, especially in our specific setting where the lack of randomization is very likely to arise because of the presence of two main sources of bias. The first one refers to the bias of "self-selectiveness" which affects those firms accessing to policy programs. As a matter of fact, it is very likely that firms benefitting from one or more policy interventions hold capability advantages (information network, research capabilities, financial soundness) over firms not involved in any policy program. This makes the former more prone to apply for policy program (as a grant or a public tender). Similarly, such a gap in capabilities between applicants and others leads to the second bias, the so-called "picking the winner" effect (Cantner and Kösters, 2012). This takes place when public agencies select firms that are already more performing than others with the aim to maximize the probability of success of their policies (Almus and Czarnitzki, 2003; Antonelli and Crespi, 2013). Both arguments provide valid rationales for hypothesizing that treatments cannot be randomly assigned because the odd of getting treated relies on a set of characteristics (X) that drive the "self-selection" as well as the selection by public agencies.

Formally:

$$E_x\{Y^1 - Y^0|T = 1|X\} \tag{3}$$

In such a situation, the comparison between treated and untreated requires to make the same kind of manipulation in order to balance the differences arisen from every potential source of bias (Aerts and Schmidt, 2008) and restore the independence assumption.

Formally:

$$E_x\{Y^1 - Y^0|T = 1|X\} = E_x\{Y^1|T = 1|X\} - E_x\{Y^0|T = 1|X\} = E_{(X,T=1)}\{E(Y|T = 1; X)\} - E_{(X,T=1)}\{E(Y|T = 0; X)\} = m_{1,1}(X) - m_{0,1}(X) \tag{4}$$

where $m_{1,1}(X) - m_{0,1}(X)$ are functions of the observables, namely Y, T, X, that can be estimated by adopting non parametric approaches. A valid option is to use the "propensity score matching technique" consisting of a randomized ex-post experiment where a reliable control group of non-treated individuals is identified. As shown in Cerulli, (2010) this method has been widely used to assess the effects of public sustain, mainly direct support, on business R&D or other outcomes. More specifically, the units belonging to the control group appear very similar to the treated units for all the observable pretreatment characteristics, that are considered relevant in influencing the probability of being treated (Heckman et al., 1998; Heckman and Navarro-Lozano, 2004). This group is used as a substitute for the non-observable counterfactual group (Caliendo and Kopeinig, 2008). Such procedure condenses the vector of relevant pre-treatment characteristics into a single scalar index, called the propensity score, which represents the probability of being treated, given the relevant covariates (Rosenbaum and Rubin, 1985). At a given value of the propensity score, the exposure to treatment should be random and therefore both treated and control units should be on average observationally identical.

In addition to the self-selectiveness and the selection process by public agencies, another source of bias in policy evaluation exercises is represented by the "hidden treatment effect". Specifically, it consists of a confounding factor arising when the effect of a treatment (RPP/IPP) is estimated without taking into account its potential interactions with other treatments aimed at the same goal and operating in the same environment. Such a problem appears to be relevant in the present analysis since the innovation policy mix in Italy mainly consists in the implementation of supply-push (SP)[9] instruments (Caravella and Crespi, 2018). As previously argued, the probability for the same firm of being involved in a double treatment scenario is not negligible, leading to biased policy effect estimates when hidden effects are not properly taken into account. Therefore, in order to eliminate possible sources of bias due to hidden treatment effects each treatment variable has been considered both in isolation and in combination with SP policies (soft loans, tax deduction and grants).

In the examined cases, as reported in Table 1, among the 4,206 firms belonging to the whole sample, 1,165 received only supply-push sustain by governments (SP_ONLY), 321 have been involved only in regular domestic contracts of public furniture (RPP_ONLY), while the remaining 321 treated firms have been interested by both SP incentives for innovation and regular public procurement contracts (RPP&SP). Finally, among firms with IPP contracts 103 of them where involved in both IPP activities and supply push instruments (IPP&SP), while 90 firms benefited only of IPP stimuli[10] (IPP_ONLY).

[9] Unfortunately, given the lack of more detailed information about the nature of the public aid received from innovative firms, we cannot distinguish between different types of instruments, i.e. public R&D subsidies, tax credits or loans.

[10] We acknowledge the limited relevance of the sample of firms involved in IPP. The results presented in this paper should be intended as a first attempt to provide evidence on this specific type of PP contracts, which has been rarely studied in a quantitative policy evaluation context of analysis.

Table 1. Description of the *m* treatments

m=0: **UNTREATED** (N=2,552)	The company does not benefit from supply-push incentives and it is not involved in any kind (regular/innovative) of domestic procurement contract (yes=1; 0= otherwise)
m=1: **RPP_ONLY** (N=271)	The company won at least one domestic regular procurement contract but does not benefit from supply-push incentives contract (yes=1; 0= otherwise)
m=2: **IPP_ONLY** (N=90)	The company won at least one domestic innovation-inducing procurement contract but does not benefit from supply-push incentives contract (yes=1; 0= otherwise)
m=3: **SP_ONLY** (N=1,165)	The company benefits from supply-push incentives but it is not involved in any kind (regular/innovative) of domestic procurement contract (yes=1; 0= otherwise)
m=4: **RPP&SP** (N=209)	The company won at least one domestic regular procurement and benefits from supply-push incentives contract (yes=1; 0= otherwise)
m=5: **IPP&SP** (N=90)	The company won at least one domestic innovation-inducing procurement and benefits from supply-push incentives contract (yes=1; 0=otherwise)

The main goal of the analysis is to compare the average treatment effect (ATT) on the outcome variable (Y) deriving from different four m treatments (namely SP_Only, RPP_Only, RPP&SP, IPP_Only, IPP&SP) with the same baseline scenario characterized by the absence of any treatment.
Formally, for a given treatment *m*:

$$ATT\ (ATET) = E(Y_i^1 - Y_i^O | m) = 1 \tag{5}$$

where Y^1 represents the outcome variable under the treatment program of interest *m* and $Y^0$is referring to the outcome variable in absence of any type of treatment (see Table 1). Hence, each treated group is compared with the same control group composed by those firms characterized by the total absence of treatment. In so doing, we can evaluate whether the effect of distinct or combined policies is positive and significant or not.

However, the evaluation of the potential complementarities between different types of instruments is complicated by additional selection bias sources that might affect the estimation of the impact for jointly treated firms. Here, we argue that firms able to access both to PP and SP policies might be structurally dissimilar from those not involved in any treatment as the two groups might well differ from each other in terms of capabilities and structural characteristics. This condition increases the heterogeneity among units and makes the two groups (treated and control) too different to be comparable even after matching (Ghisetti, 2017). Hence, a feasible way to correctly identify the existence of complementarities between distinct instruments is to compare the double treated units (RPP&SP and IPP&SP) with a reduced group of controls which is obtained by restricting the analysis to firms with at least one treatment and dropping the initial control units (firms not benefitting from any type of public policies). This may allow to increase the level of firms' homogeneity in the two groups (treated and control) as units treated once are supposed to be more similar to the double treated ones. Such a procedure, only followed for the double treatments, works as sensitivity test. In that, the ATET of jointly treated firms is compared with two control groups: (1) a control group comprising firms only benefitting from SP policies; (2) a control group formed by recipients of only PP policies (RPP_ONLY or IPP_ONLY according to the case of analysis).

4.2 The matching procedure

In order to artificially create the counterfactual setting $E(Y^0|m=1)$, i.e. the outcome that the treated unit would have performed in the absence of treatment, the best pairs of treated and control firms have been identified by exploiting the propensity score matching for each of the five treatments (*m*) on the basis of the pretreatment characteristics (X) potentially able to affect both the treatments and the target variable. In so doing, we implement a number of logit models in order to compute the conditional probability of receiving the treatment given the above set of covariates (X).

Table 2. Variables description (N= 4,206)

VARIABLE	Description	Mean	Standard Deviation
Bank_rate	The bank interest paid by the company on bank loans	2.30	1.50
Size	Logarithm of the turnover	17.12	1.83
2Size	Logarithm of the turnover (squared term)	296.11	58.64
Group	The company is part of a group (yes=1; 0=otherwise)	0.72	0.44
High-tech	The company operates in high-tech or medium-tech manufacturing sectors (yes=1; 0=otherwise)	0.37	0.48
Low-tech	The company operates in medium or low-medium-tech manufacturing sectors (yes=1; 0=otherwise)	0.67	0.46
Export	The company sells in foreign markets (yes=1; 0=otherwise)	0.90	0.29
Log_K	Ratio between capital assets and turnover[a] (logarithmic)	8.47	2.30
Outcome Variable			
R&D/Turnover	Ratio between R&D expenditures on turnover (percentage)	2.32	5.45

To provide unbiased estimated of ATT by using the generalized propensity score estimator, three assumptions need to be satisfied. The first is the conditional independence condition (CIA), also known as "confoundedness" assumption, which requires that all the systematic differences between "treated" and "untreated" units are removed through the *observable* variables identified as covariates (X)[11]. In other words, once it is controlled by

[11] The implications of CIA are discussed in Cerulli (2015).

the set of X, the potential outcomes are independent from treatment assignment. Given the difficulty to directly verify this strong assumption, we select all the covariates that could allow the condition to hold. The second condition is the SUTVA (Rubin, 1978), i.e. stable unit treatment value assumption, which assumes that treatment applied to one unit does not affect the outcome for another unit. Finally, the third condition refers to the "common support" assumption according to which covariates themselves (X) should not perfectly predict the probability of receiving one specific treatment. The satisfaction of all these conditions allows the generalized propensity score matching estimator to consistently estimate the ATT.

The first focus variable capturing the "input additionality" in the present analysis is represented by the total expenditures in internal and external R&D activities over the three-year period, whose use is very common in the literature (e.g Almus and Czarnitzki, 2003; Carboni, 2011; Mulligan and Doran, 2017). This amount has been divided by the mean of turnover referring to the same time window (R&D) since expressing target-variables in ratios instead of levels allows for the reduction of collinearity with firms' size (Carboni, 2011) and ensures less volatile results (Cerulli and Potì, 2012).

The covariates adopted for the implementation of the propensity score method have been identified according to those aspects recognized by the literature as relevant in influencing the participation to innovation policy programs as well as stimulating private R&D expenditures and innovative turnover. The summary statistics have been reported in Table 2.

To properly control for firms' propensity in investing in R&D, a measure of financial constraints proxied by the bank interest paid by firms on their bank loans (*Bank_rate*) has been included among the regressors[12]. Many theoretical arguments justify the close relationship between financial constraints and R&D expenditures through the "financing gap hypothesis", according to which most R&D projects are founded by firms' internal resources instead of external ones. This is due to the difficulties faced by external investors in assigning the right value to the intangible assets created by R&D efforts and thus, in distinguishing good projects from bad ones. As a result, financial institutes could be reluctant towards R&D investments with the effect to create financial constraints and credit rationing (Bond and Meghir, 1994; Fazzari et al., 1988; Hoshi et al., 1991), by making R&D investments more sensitive to firms' internal financial resources (Hall, 2002; Hall and Lerner, 2010; Hall et al., 2016; Scellato, 2007). In the case of liquidity constraints, the additional public financing works as an exogenous injection of cash-flow thus producing a positive increase of R&D expenditures (Cerulli and Potì, 2012). In this framework, financial constraints represent one of the main rationales beyond government intervention (Takalo and Tanayama, 2010) since firms affected by financial/liquidity constraints have

[12] Other measures typically used for financial constraints (as for instance indebtedness represented by bank debts) are not adopted because they are missing for many observations.

been found particularly oriented towards government funding (Lach, 2002; Gonzalez et al.*,* 2005; Czarnitzki and Toole, 2007; Hyytinen and Toivanen, 2005). To construct the *Banck_rate* variable, the logarithmic transformation has been applied to the interest rate variable by adding one to avoid dropping zeros. A second regressor (*Size*), measured here by the logarithm of turnover referring to the first year of each three-year period considered, aims at capturing the influence of firms' dimension. In line with the "financing gap' hypothesis" sustaining the importance of internal financial resources in stimulating R&D investments, bigger firms tend to have larger cash flows. In addition, large firms could have more possibilities to engage in innovation activities thanks to better organization, easier access to financial markets and better opportunities to overcome the innovation-related barriers (Savignac, 2008; Pellegrino and Savona, 2013). The squared term of firm's size is included to control for possible nonlinear effects (*2Size*). In the same vein, we further control for group affiliation (*Group)* which may influence the amount of resources available to engage in R&D for affiliated firms, as well as their capacity to route the procedure for being engaged in public programs (González et al., 2005; Hussinger, 2008; Aristei et al., 2015).

Furthermore, we include two dummies variables referring to the high and low technology intensity of firms' sector (*High-tech* and *Low-tech*)[13]. The rationale for this inclusion is strictly linked to the positive relationship between being a firm operating in the high-tech sector and the likelihood of benefitting from policy innovation programs (Divella and Sterlacchini, 2018). Yet, in order to take into account the self-selection bias due to higher capabilities required to firms to be involved in policy programs (Huergo & Moreno, 2017), an export dummy (*Export*) has also been included among the regressors as firms operating in international markets might show higher innovative propensity than national market focused enterprises (Arnold and Hussinger, 2005) and could have higher capabilities in dealing with bureaucratic procedures compared with non-exporters (Takalo et al.*,* 2013). In addition, since more capital-intensive firms may have higher commitments to innovation than more labour-intensive ones (Carboni, 2011), a capital intensity variable is included. It is measured as the logarithm of capital assets (*LogK*) referring to the first year of each tree-year period considered. Finally, macro-area dummies accounting for firms' localization (North, Centre and South) are included in the PSM estimates.

The goodness of the matching performance referring to the ability of the matching procedure to balance the distribution of the co-variates in both treated and control groups is provided by the fact that in the matched sample the standardized differences are all

[13] With respect to high and low-tech industry, we have followed the OECD ISIC Rev. 3 technology intensity definition of manufacturing industries (OECD, 2011). In particular, we have grouped together firms in high and medium-high technology sectors into the unique category of high-tech industry; likewise, firms in low- and medium-low technology sectors have been grouped together in low-tech industry.

close to zero, and the variance ratios are all close to one. This is confirmed for each procedure, regardless to the composition of the control group. In fact, both when the controls are never (Figures 3 and 4) and once treated (Figures 5 and 6), the graphs confirm the goodness of the matching procedure, as the distribution of the estimated propensity score before and after the pairing procedure signals the good quality of the procedure given the significant reduction in the dissimilarities between treated and control distributions after the matching. In addition, the overlap assumption is not violated as the estimated densities have most of their respective masses in regions in which they overlap. Yet, the validity of the matching procedure is supported by all tests for matching quality. Firstly, the reduction of the mean standardized bias falls below 5% threshold, a condition which is already a sufficient to ensure the success of the pairing procedure (Rosenbaum and Rubin, 1985). Secondly, the pseudo R-square values are lower for matched firms when compared with unmatched ones. This evidence, suggesting that less variance is explained by the set of covariates in the matched firms, implies that the treated and untreated units are very similar to each other (Sianesi, 2004). Thirdly, the log-likelihood ratio tests on differences in covariates means are rejected before the matching and not rejected after the matching, showing that all *p-values* are lower than 0.05 (Ghisetti, 2017).

Figure 3. Distributions of the propensity score for the treated (RPP_Only, SP_Only, RPP&SP) and the not-treated group before (SP=0 & RPP=0) and after (red line) the matching

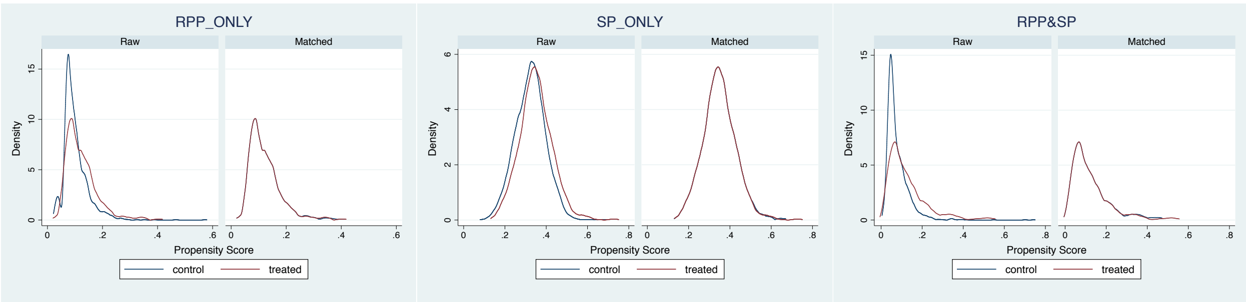


Figure 4. Distributions of the propensity score for the treated (IPP, IPP_Only, IPP&SP) and the not-treated group, before (blue line) and after (red line) the matching

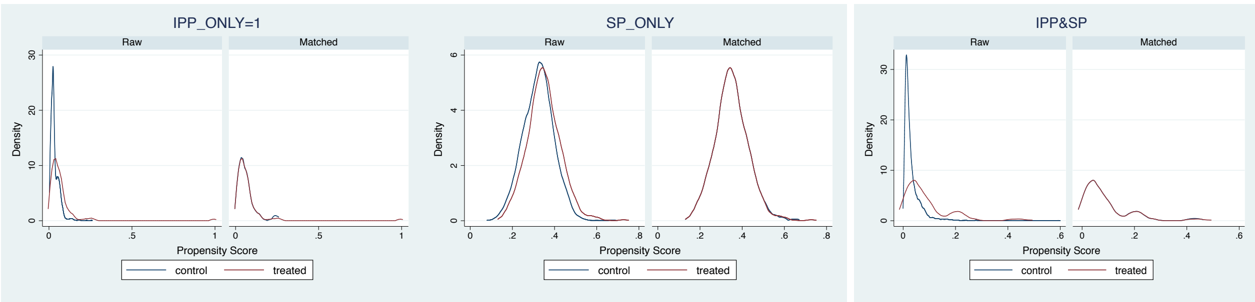


Figure 5. Distributions of the propensity score for the treated (RPP&SP) and the not-treated group (SP=1) and & RPP=1) before (blue line) and after (red line) the matching

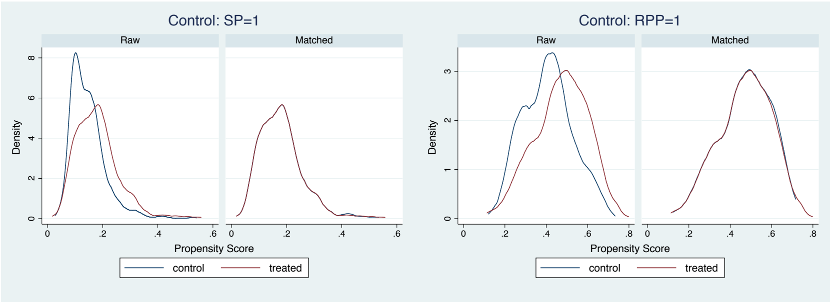
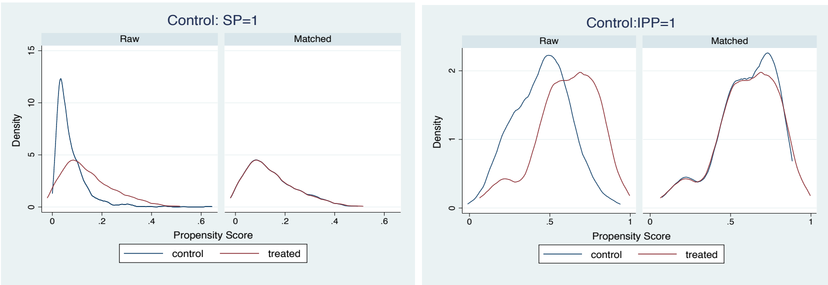


Figure 6. Distributions of the propensity score for the treated (IPP, IPP_Only, IPP&SP) and the not-treated group, before (blue line) and after (red line) the matching



5. *Impact evaluation results*

The results of the impact evaluation analysis are reported in Table 3. To better balance the *trade-off* between bias and efficiency, different algorithms have been used (Caliendo and Kopeinig, 2008). Considering that, in most of cases, the dimension of the control group largely exceeds that of the treated group, the 3NNM method has been chosen in order to increase the efficiency of the estimates[14]. This technique consists in the identification of three observations which are closest to the treated unit in terms of propensity score values. As robustness checks, we resort to the implementation the Kernel method, after that coefficients remain largely unchanged with respect to both the significance and the sign of the impact.

[14] The *teffects psmatch* command in Stata14 is used to calculate ATT, since it estimates standard errors adjusted for the first-step estimation of propensity scores, as suggested by Abadie and Imbens (2016). The balancing property of the propensity score is tested using the Becker and Ichino (2002) user-written Stata command *pscore* and is always satisfied.

Table 3. Impact evaluation results (1)

ATT (ATET)		Control sample N= 2,552 (m=0: UNTREATED)
m=1: RPP_ONLY(N=271)	3NNM	-0.797*(0.4304)
	Kernel	-0.797**(0.3071)
m=2: IPP_ONLY(N=90)	3NNM	0.392(0.4327)
	Kernel	0.3023(0.6915)
m=3: SP_ONLY(N=1,165)	3NNM	1.214***(0.2354)
	Kernel	1.214*** (0.2918)
m=4: RPP&SP(N=209)	3NNM	1.437**(0.6215)
	Kernel	1.437** (0.6415)
m=5: IPP&SP (N=103)	3NNM	2.780***(0.9386)
	Kernel	2.780***(0.6415)

Note: Standard error in parentheses. * p< 0.1, ** p< 0.05, *** p< 0.01

Interesting findings emerge from the results provided by the non-parametric analysis. Since the outcome variable is expressed as the percentage of total R&D expenditures over firms' turnover, the interpretation of the average effect of being involved in one of the *m* treatments is almost immediate.

Starting from the comparison between treated and untreated (Table 1), we observe that the average effect of receiving a regular procurement contract without benefitting from supply-side incentives (m=1) is negative and statistically significant. In particular, we find that companies exclusively involved in this kind of treatment show a ratio between R&D expenditures and turnover which is 0.79 p.p. lower than that recorded for untreated firms (m=0). This means that, in terms of innovative performances, firms involved in RPP contracts display a lower intensity in R&D investment with respect to their (untreated) peers. The reason that might explain why firms operating within *regular* procurement schemes have less incentives to compete on markets through innovation-levers can be twofold. Firstly, the suppliers of public administration tend to benefit from flows of demand that can be more stable and less volatile than those faced by firms selling on private markets. Indeed, supplies are likely to be less exposed to external turbulences (Kimura, 2002) - such as growing competitive pressures, market internationalization processes and increasing complexity in product technologies- all elements that, on the contrary, are relevant factors in pulling firms towards competitive and pro-innovation behaviours. Secondly, *regular* procurement activities generally lack of any element of technological novelty and tend to look mainly at static efficiency issues. This might imply that suppliers are able to fulfil the needs expressed by the public entities without engaging in innovation-related investments. These effects appear to be particularly relevant in the Italian case, where, as discussed, the level of institutional capabilities are rather limited.

With respect to the IPP category, we discover that, when not sustained by *supply-side* measures (m=2), companies awarded IPP tenders do not overperform their untreated peers in terms of R&D expenditures. Thus, we conclude that requiring advanced and innovative products does not represent a sufficient condition for ensuring additionality on R&D expenditures. This might be the case in which firms with IPP contracts are already equipped with sufficient knowledge and technological capabilities for satisfying their client demand. If this occurs, no additional efforts in generating new technological knowledge are required. As stated by Czarnitzki et al., (2018), the low technological complexity of IPP tenders could be a relevant element potentially explaining why IPP suppliers are more oriented towards incremental innovation or mere imitation instead of being attracted by original and creative activities, whose engaging would require considerable investment in R&D. This is likely the effect that we observe in the analysed context given the low intensity of innovation and administrative capabilities that characterise the Italian innovation system.

A different picture emerges with regard to the effectiveness of SP policies. In this case, being recipients of SP policies (m=3) turns out to be a sufficient condition for R&D additionality. In particular, the additional R&D investment realized in the presence of supply-side incentives increases the R&D/Turnover ratio by 1.21 pp. Hence, our results confirm, after controlling for selection bias related issues, the success of supply-side incentives in dealing with certain types of market failures related to innovation activities, such as financial barriers and appropriability problems (Busom et al., 2014). This evidence mirrors previous results provided by non-parametric matching analyses, most of the them in favor of the additionality hypothesis (see for example Almus and Czarnitzki, 2003; Czarnitzki and Licht, 2006 González and Pazó, 2008, Bronzini and Iachini, 2014; Guerzoni and Raiteri; 2015).

The next step of the analysis allows us to see what happens when firms are touched by both demand-pull and supply-push stimuli. The results reported in Table 3 show that positive and significant effects on private R&D expenditures also stem from the double treatment (RPP&SP and IPP&SP). In particular, we observe that when combined with SP policies, firms benefitting from RPP/IPP contracts display a ratio between R&D expenditures and turnover which is higher than that recorded by untreated firms (m=0). More in detail, the ATT associated with the RPP&SP treatment is equal to 1.43, while the additionality effect of the IPP&SP variable on R&D is about 2.78. Such a finding appears to go in the direction of the "complementary thesis" among different policy innovation tools (EU, 2009; Martin, 2016), showing that the positive impact of demand-side policies is activated only when the latter are framed within an "holistic approach" (Borrás and Edquist, 2013) in which SP and PP measures are jointly.

However, as previously stated, these results on the effectiveness the policy mix in promoting innovation need to be further qualified. Results provided in Table 3 would be in line with findings as in Guerzoni and Raiteri (2015), where the same non-parametric framework is applied to compare double treated units to untreated ones (m=0). In order to dig further into this issue, we enrich the analysis with some sensitivity checks aimed at better controlling for selection issues. In particular, we argue that compared to companies that do not participate in any policy programs (m=0), firms involved in at least a single policy (m=1, m=2 and m=3) are more close to those getting into a double policy treatment (m=4 and m=5) in terms of research capabilities, network interactions and structural characteristics. Building on these considerations, the purpose of this robustness check is to reduce the "ex ante" heterogeneity among firms, thus performing the comparisons with the most homogeneous samples of treated and controls. Table 4 reports the results from the "new" matching analysis, providing further evidence on the actual impact of the policy-mix.

Table 4. Impact evaluation results (2)

		Column 1	Column 2	Column 3
			Control group	
		m=1: RRP_ONLY (N=271)	m=2: IPP_ONLY (N=90)	m=3: SP_ONLY (N=1,165)
ATT (ATET)				
m=4: RPP&SP(N=209)	3NNM	1.667***(0.4632)		0.425(0.4486)
	Kernel	1.667***(0.5443)		0.425(0.6727)
m=5: IPP&SP (N=103)	3NNM		3.280***(1.0257)	1.901**(0.9267)
	Kernel		3.280***(0.9926)	1.901**(1.0529)

Note: Standard error in parentheses. * p< 0.1, ** p< 0.05, *** p< 0.01

In this case we compare the R&D intensity of double treated firms (m=4 and m=5) with that of firms treated only once (m=1,2,3).

Starting from the comparison between m=4 and m=1 groups, we observe a positive and significative difference in the outcome variable (column 1). This suggests that when firms involved in RPP contracts are also interested by SP policies, they show a higher ratio between R&D expenditures and turnover (+1.67pp). However, such a difference vanishes when the comparison occurs between m=4 and m=3 groups (column 3), suggesting that for SP treated firms the presence of RPP as an additional policy stimulus does not lead to any difference in the intensity of R&D efforts. This result contrasts with that provided in Table 3, where the policy mix RPP&SP was found to be effective. Here we prove that such a result (which was in line with previous literature both in terms of results and in terms of methodology adopted) was misleading because of the presence of *a priori* dissimilarity between treated and untreated pairs, that we now better control by using more homogenous control groups (m=1 and m=3).

On the other hand, with regard to the IPP case, findings remain in favor of the "complementarity thesis". Indeed, looking at column 2 where m=5 and m=2 groups are compared, it emerges that among the IPP suppliers those benefitting from SP policies have a greater intensity in R&D activities (+3,2pp). Furthermore, when the comparison concerns the groups m=5 and m=3 (column 3), the positive effect of the IPP&SP is confirmed. In this case, among firms involved in SP policies show a positive R&D premium (+1.9pp) when involved in IPP activities. In this case, the sensitivity check confirms the superior impact of a policy mix acting both on the supply and demand sides with respect to the case of a single policy. However, as shown by the higher R&D premium attached to SP effects (column 2) with respect to IPP impact (column 3), the main contribution to the complementarity effects in the mix is driven by the presence of supply-side incentives. Such an evidence is very close to those emerging in Stojčić et al., (2019) for Central & Eastern Europe where, despite of the encouraging finding discovered for the policy mix instrument, the supply channel is found to strongly prevail on demand-pull tools.

6. *Conclusions*

Focusing on the Italian case, the present paper investigated the impact of *demand-side* measures on firms' R&D investments by distinguishing between regular procurement contracts (RPP) and innovation-inducing procurement contracts (IPP). In so doing, the study contributes to the existing literature by enlarging the quantitative evidence on the effectiveness of *demand-side* policies thanks to the detailed information provided by the Italian Community Innovation Survey. Moreover, from a methodological perspective, the proposed analysis complements previous evidence by paying particular attention to selection-bias issues that might affect the reliability of results. This is done by framing the exercise in the context of non-parametric analysis, thus controlling for the presence of other policy actions, in specific supply-push instruments, as potential source of bias and better solving further bias-related issues through a number of sensitivity checks.

Taken together, findings stemming from the whole empirical analysis provide relevant suggestions on the actual effectiveness of demand-pull and technology-push instruments as well as their combination into a policy mix. In particular, we confirm previous evidence on the key role played by SP policies in fostering firms' R&D expenditures decisions. Secondly, we found that public procurement when not designed in a way that specifically stimulates innovation (RPP) is not able to stimulate additional R&D investment. On the opposite, RPP suppliers display a lower propensity to innovation activities compared to non-treated firms, when not involved in SP programs. Third, we find evidence that, even when explicitly aimed at innovation purposes (IPP), the success of demand-pull policies is ensured only under certain conditions. In particular, we show that IPP is effective in stimulating innovative activities when firms also benefit from supply-side tools.

Such a finding suggests that, even in presence of a weak procurement system, as that characterizing countries like Italy, when IPP activities are framed into a "policy mix" setting, a positive effect on innovation activities is generated. This evidence supports the "holistic" approach to innovation policy suggesting that SP policies can be fruitfully complemented by demand-pull instruments also in the Italian case where SP, tax-based incentives are prevalent (Caravella and Crespi, 2018). Considering that in 2018 Italy has spent about 181 billion of Euros in procurement activities while the percentage of the firms with contracts inducing innovation amounts to 3,1%, the potential of this instrument is large and there is room for enhancing and enlarging the innovation-triggering role of public demand. This would require a more declared pro-innovation nature of this instrument as well as its inclusion in a more comprehensive innovation policy toolbox. In this respect, Italian procuring agencies have to overcome their high-risk adverse attitude to demand innovative solutions and abandon a pure cost-effectiveness and statistic-efficiency approach to increase the innovative content of their demand (EC, 2016; Lember et al. 2015; Rolfstam, 2009; Amann and Essig, 2015; Georghiou et al., 2013; Albano and Sparro, 2010).

Finally, we recognize that our results are not exhaustive and that further research is needed to investigate the examined issues. Firstly, it would be interesting to compare the results obtained in the Italian case with those of other countries. Secondly, concerning the complementarity impact form IPP and SP instruments, it would be worth to distinguish between different SP tools, in particular public R&D subsidies, tax credits or loans. Moreover, it would be interesting to evaluate the impact of different instruments by having information on the monetary amount of both procurement contracts and SP incentives. Finally, the use of data with qualitative information on the tender would allow for a better identification and comprehension of the mechanism related to the procurement and innovation nexus.

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