Is excessive public procurement a brake on firms' innovative output?

An analysis applied to the Italian context

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This article investigates the relation between public procurement (PP) and firms' innovation, by analysing information on Italian firms. Taking advantage of the peculiarities of the Italian context, I test whether procurement firms report a higher propensity to innovate, and whether this propensity varies with the level of PP a firm engages in. Even in a country with a high polarisation in firm performance, PP is found to be associated with an increase in the probability of innovating, although this result is limited to micro/small firms, low shares of PP, and firms having product innovation as their target.

Questo lavoro indaga la relazione tra public procurement (PP) e innovazione di impresa. Sfruttando le peculiarità del contesto italiano, si verifica se le imprese coinvolte in PP segnalino una maggiore propensione all'innovazione e se tale propensione vari con il livello di PP che impegna un'impresa. Anche in un Paese con una grande polarizzazione nella performance d'impresa, il PP risulta essere associato ad un aumento della probabilità di innovare, sebbene questo risultato sia limitato alle micro/piccole imprese, a quote basse di PP ed alla conduzione di innovazione di prodotto.

DOI: 10.53223/Sinappsi_2022-03-4

Citation
Augliera M. (2022), Is excessive public procurement a brake on firms' innovative output? An analysis applied to the Italian context, *Sinappsi*, XII, n.3, pp.66-91

Keywords
Public procurement
Enterprises innovation
Small and medium-sized enterprises

Parole chiave
Appalti pubblici
Innovazione delle imprese
Piccole e medie imprese

Introduction

The promotion of private innovation has reached in recent years a preminent position in the agenda of policy makers, innovation being largely acknowledged as a key driver to spur firms' growth (Geroski 1999; Delgado-Gomez and Ramirez-Aleson 2004; Coad and Rao 2008) and, in turn, to support a country's economy in the long-run (Dosi *et al.* 1990; Aghion and Howitt 1992). Periods of time of continued budgetary pressure have pushed policymakers to search for and adopt new appealing ideas other than the traditional supply-side measures to redirect public spending towards innovative solutions with little to no extra money (Czarnitzki *et al.* 2018). It is in this context that public procurement (hereinafter, PP) – acknowledged to be a noteworthy market force, considering its magnitude[1] – has gained a revitalized interest from both practitioners and scholars as a tool to promote innovation (Thai 2015), though its capability to exert a beneficial impact on firms has been neglected for many years (Edler and Georghiou 2007).

Recent contributions (Aschhoff and Sofka 2009;

1 Data from OECD show public procurement represents a substantial proportion of government expenditure (spanning from 20% to 45% in 2015) and national GDP (from 6% to 21% in 2015) (OECD 2017), to the extent to be regarded by some scholars as the largest business sector in the world (Hawkins *et al.* 2011).

Guerzoni and Raiteri 2015; Stojčić *et al.* 2020) seem to suggest that PP contracts exert a beneficial impact on firms' innovation, although the empirical investigations are still far from providing clear cut results. Therefore, the aim of this work is to enrich the debate in this strand of the literature by tackling the following main aspects.

The first aspect is to strengthen the assessment of the relation between PP and firm innovativeness by controlling for a richer set of firm-related variables, thus lowering potential biases. To do so, I exploit Italian firm-level longitudinal data based on the most recent employer-employees RIL survey waves (2015, 2018), which provide the advantage of taking into account different aspects of firms' heterogeneity. This opportunity enables us to extend the analysis by shedding light on the peculiar context of Italy, which is a sound case of study for its persisting weaknesses that are at the root of the poorly reassuring trend in productivity and innovativeness in the last two decades, thus leading to the practically stagnant growth in GDP (Bugamelli *et al.* 2018). Among all, the fragmentation of the larger firms is a noteworthy one, micro and small firms being predominant, as well as firms' lower aptitude for innovation with respect to its main European partners (Brandolini and Bugamelli 2009; Bugamelli *et al*. 2012). Features that are intertwined (Pagano and Schivardi 2003; Lotti and Schivardi 2005) following, for instance, the higher difficulty by smaller firms to sustain fixed costs in RandD as well as to gather proper resources to address investments and to exploit economies of scale ascribable to technological innovations (Freel 2003; Lee 2009; Müller and Zimmermann 2009). Features that, additionally, are called to impact on the expected result the literature attributes to PP (Loader 2005; Karjalainen and Kemppainen 2008; Flynn and Davies 2017).

The last point, which represents the main aspect of this work, is to investigate whether the potential effect on innovation exerted by PP is affected not solely by contracting/not contracting PP but, also, by the incidence of PP contracts on firm business. I advance this point, which, to the best of my knowledge, represents a novel feature in this type of empirical investigation, considering the complexity implied in procuring to public bodies due to the strict provisions that regulate any call for tenders. Indeed, firms need to put a certain effort to manage all the steps within a call for tenders (Flynn *et al.* 2013; Loader 2015; Flynn and Davies 2017) and to challenge the offers from competing firms, with the risk of suffering from diverting precious resources to be used for alternative uses.

The remainder of this work is organized as follows. Section 1 reviews the literature on PP as a tool for innovation policy, presenting also previous empirical evidence supporting the theoretical argumentation. The research questions and the hypotheses that I advance are introduced in Section 2. In Section 3 I introduce the database as well as present some descriptive statistics on the variables of interest. In Section 4 I conduct the empirical analysis and I further check the robustness of the outcomes recurring to further methodologies and model specifications. Eventually, the conclusions are drawn in the last section.

1. Theoretical and empirical literature

The issue of PP, which represents the demand-side policies' main operative tool, has solely recently caught a new revitalized interest in policymakers as a tool to boost innovativeness in firms (Edler *et al.* 2015; Uyarra and Flanagan 2010; Caravella and Crespi 2021), though several pioneering contributions already accounted decades ago for the possibility to demand-side policies to exert potential benefits on innovation. For instance, preliminary contributions suggested that procurement could be more likely to generate innovations than RandD subsidies (Rothwell and Zegveld 1981) or could positively impact on firm's propensity to engage in RandD (Lichtenberg 1989). In a similar vein, Geroski (1990), after reviewing a series of innovations emerging from PP, concluded that, should certain conditions be met, procurement was an effective means to stimulate innovation, by exerting a role in creating demand for new products and processes, in making an already-existing demand visible, and providing a minimal market size in the early stage of innovation.

An element signalling the revitalized interest in PP as a tool to incentivize firms' innovative behavior is without any doubt the elaboration of the *innovative procurement* concept (Edquist and Hommen 2000). This concept represents, within the debate, a first attempt to enlarge the scope of PP as well as to acknowledge its supplementary mission, since innovation becomes a requirement of the

tender contract to be fulfilled. According to this new concept, further developed by Edquist and Zabala-Iturriagagoitia (2012), innovative procurement occurs when "*a public agency places an order for a product or a system which does not exist at the time, but which could probably be developed within a reasonable period*" (Edquist and Hommen 2000). A type of procurement that the public sector may be willing to employ, as it offers the opportunity to acquire new technologies and innovative products/services without a direct operational involvement but, rather, leaving to the creativity of private business the way to achieve the level of desired output (Aschhoff and Sofka 2009). As a result, what emerges from such a concept is a split within the procurement family, as innovative procurement detaches from a sort of standard procurement, the latter limited to the original way of understanding PP, that is the mere satisfaction of the basic needs of the public sector, for instance the purchase of ordinary products for office tasks[2].

The introduction of the procurement concept embodies undoubted advantages in strengthening a hypothetical positive relation between procurement and innovation. Certainly, it goes without saying that, by definition, the explicit request for innovative content is already conducive to a positive change in firms' innovative behavior (Guerzoni and Raiteri 2015), as competing in a call for such a type of procurement provides *per se* the expectation for the participant firms to be involved in advancing innovative solutions. Several contributions trace a spur to investments in RandD in awarded firms as well as upgrading in technological and competitive capabilities back to the expansion in the market originated from a direct demand for goods/services that do not exist yet (Mazzucato 2015; Edquist 2015; Caravella and Crespi 2021). A spur that was also suggested to stem from a reduction in development costs, since procurement contracts may provide firms with an ideal niche where to develop more easily new products, even by virtue of precious access to users' prolonged feedback (Lember *et al.* 2015), as well as the opportunity to get acknowledged, to possible forthcoming market trends, resulting in a firm that is better prepared to address its business (Stojčić *et al.* 2020). By the same token, it has been suggested that innovative procurement may not be limited influencing the innovative attitude of firms, since even 'where' to innovate is an aspect that should not be neglected (Ghisetti 2017). For instance, PP may be used to stimulate private providers to carry out RandD in areas with strong social needs where the market interest is underdeveloped due to a low private rate of return and high uncertainty (Stojčić *et al.* 2020).

An interesting argument that has been raised is whether an enhancement in innovative attitude is a prerogative of solely those procurement contracts with an explicit requirement to come up with innovative solutions, or, rather, even standard PP is capable of positively affecting innovativeness in firms. Since the large purchasing capacity of public sectors as well as the often-prolonged terms in procurement should not – reasonably – vary on the content requirement, these characteristics may be in any case beneficial to awarded firms. For instance, firms may exploit their status as government suppliers to signal to external investors their reputation (Caravella *et al.* 2021) and to access credit more easily, ultimately improving their capability to undertake investments (Hebous and Zimmermann 2016). On this issue, it has been highlighted that a clear-cut distinction between innovative and standard procurement may be ineffective since the definition of innovative PP constrains its scope to the activities that follow a formal tender process (Uyarra and Flanagan 2010). In other words, PP may not necessitate to explicitly refer to innovative content at tender stages to lead to – *strictu sensu* – innovations, since there may be room for indirect channels through which a PP contract stimulates firms' innovative behavior (Cave and Frinking 2003). Indeed, the already cited definition of innovative procurement excludes many categories of innovation and, so, downplays the

2 It is useful to report that the elaboration of the innovative procurement's concept is not alien to extra-academic contexts. For instance, the same European Commission has developed its own way to mean public procurement in terms on innovation, distinguishing between 'Pre-commercial Procurement' and 'Public Procurement of Innovative Solutions'. In the first case, the contract's object is the purchase of RandD services that are likely to give rise to entirely new goods or services, whereas, in the second one, "*the contracting authorities act as launch customer for innovative goods and services that are not yet available on a large-scale commercial basis*" (European Commission 2014, 12).

possibility that indirect impacts, as well as spillover effects, take place (Uyarra and Flanagan 2010). Not by chance, conceiving innovative procurement as the procurement of something that does not exist yet appears problematic as it is biased towards radical innovation, leading to an idea of innovation as synonymous with complete novelty which rarely occurred (Abernathy and Clark 1985), as demonstrated by referring to many of the most frequently cited examples of PP-induced innovation that, instead, did not result from an intentional or conscious drive to encourage innovation (Uyarra and Flanagan 2010). Following this argument, it should be more appropriate to refer to *innovation-friendly procurement* practices, since innovation may be influenced at different stages of product technology and not just at early stages (Uyarra and Flanagan 2010; Rolfstam 2012). For instance, besides being more inclined to risks in developing new products, a certain number of sales is guaranteed by contract (Stojčić *et al.* 2020), procuring – irrespective of the contractual requirement – may represent a stage to develop new routines and capabilities as well as to improve reputation and credibility and to reduce learning costs thanks to the engagement in a collaborative and developmental relationship (Raymond 2008). Effects that, admittedly, may widen beyond a firm's edges. Enlarging the market for new goods, changing the market structure, and encouraging diffusion through the convergence to single standards are examples of further indirect effects of PP as suggested in Cabral *et al.* (2006).

Despite this list of benefits attributed to the involvement in PP, some authors have warned about a hidden face of PP. By providing firms with immediate sales opportunities, Chang (2017) argues that PP may hide a risk of moral hazard as firms may exploit PP as a sort of shelter to mitigate the pressure to innovate as a precondition to remain on the market. Also, Akcigit *et al.* (2018) acknowledge PP as an opportunity firms may exploit to be protected from competing with more efficient firms in the private market. Yet, to do so firms have to invest in political connections rather than in productive capital since connected firms are more likely to be awarded a contract. Not by chance, business ties with the public sector through procurement may depend on elements which are not necessarily linked to the degree of innovation of the offered product/service or the level of productivity, which in turn impacts the ability to offer a winning rebate. For instance, the public sector may privilege firms with previous public contract experience and/or opt to maintain regular suppliers in order to guarantee a satisfactory service and/or to avoid switching costs (Uyarra and Flanagan 2010). In a similar vein, Cappelletti and Giuffrida (2021) used this argument to interpret the evidence that procurement firms show large survival rates than their counterparts. Following the reasoning, public demand does not necessarily select the most efficient firms, as governments may still opt to protect inefficient firms from market competition in order to meet policy goals of interest. Therefore, the authors argue the result may depend on firms that see their dependence on government contracts increased. A further point that may be advanced regards the issue of resource diversion. To get sufficient chances to secure a public tender, firms have to invest in costly and – often – time-consuming activities, which inevitably subtract resources to address competitive pressures within the market. Analogously, it may not be excluded that an 'investment' in tenders' activities provides a firm with an advantage with respect to more performant or innovative firms. Therefore, the larger the involvement, the larger the diversion of resources that may be alternatively employed in RandD programs, hence undermining the capability to be innovative. An involvement that is not subject to the pursuit of an economy of scale in managing the activities behind PP tenders, as each call for tenders differs from the others in terms of content, requirement, and procedures to be fulfilled, the latter often hiding impediments firms have to clear first (Flynn and Davies 2017).

When it comes to empirical evidence on the relation between PP and innovation, most of it originates from case studies which, generally, provide hints on a positive nexus (Rolfstam 2009; Uyarra and Flanagan 2010; Flanagan *et al.* 2011). Regarding micro-level quantitative studies, their number is increasing over time, though preference has been largely given to PP contracts that specifically require innovative content. Even in this case, robust evidence of a positive effect has been widely reported. The relation between PP and innovation has often been analyzed within the context of a policy-mix, that is by taking into consideration the concurring presence of supply-side measures. In the

article by Aschhoff and Sofka (2009) – one of the first quantitative analyses on the issue – the effects of PP on innovation are compared with those stemming from other forms of public support, like, for instance, RandD subsidies. Using data from the Community Innovation Survey (CIS) regarding the innovation activities of German enterprises in the period 2000-2002, PP is found to exert a positive and significant effect on innovation success, measured as sales with new-to-the-market products. The impact on a firms' innovation performance is heterogeneous, being procurement effective, in particular, for smaller firms in regional areas under economic stress and in distributive and technological services. Similarly, focusing on the interaction between traditional supply-oriented measures and innovative PP in a sample of 27 EU member states, Guerzoni and Raiteri (2015) find the latter effective in stimulating private expenditure in innovation output, with an impact even larger than that exerted by RandD grants. Based on this finding, the authors highlight the existence of a reinforcement effect, that is PP — both as a separate policy and within a policy mix — is useful to encourage innovative behavior. In a similar vein, also Stojčić *et al.* (2020) detect and confirm the existence of a reinforcing effect in their analysis of several policy instruments in eight EU countries in transition from middle to high-income levels. So, like in the previously mentioned article, firms receiving PP for innovation contracts have a higher probability of innovating and achieve higher sales from new products. Yet, supply policies emerge to be dominant in a situation when PP contracts do not require to come up with innovative content. Positive effects stemming from innovative PP are found also in Czarnitzki *et al.* (2018). Using data on German firms from the 2010-2012 CIS survey, the authors find that PP with contracted innovations exerts a large and robust effect on firms' share of turnover from selling new products and services, whereas standard PP remains insignificant.

Concerning the Italian context, interesting hints can be derived from the work by Divella and Sterlacchini (2018), who compare two different institutional and economic contexts, namely Italy and Norway. The evidence they provide suggests that firms engaging in regular PP do differ with regards to those engaging in innovative PP in terms of several firms' characteristics. For instance, firms reporting innovation related to PP, perform better in terms of RandD activities and level of human capital. Caravella and Crespi (2021) do also find that innovative PP has a beneficial effect on RandD investments, yet solely in association with supply-side measures like tax deduction and grants. In a similar work, the same authors find that firms engaged in PP grow more than their counterparts that limit their business to selling goods to households, but less than those firms that supply private firms (Caravella *et al.* 2021). Interestingly, the beneficial effect on growth appears irrespective of the procurement type, although innovative procurement is found to be particularly strategic in favoring already innovative firms. This latter point winks at the result in Slavtchev and Wiederhold (2016), who find evidence that a shift in the composition of public purchases towards high-tech industries induces an increase in aggregate RandD investments.

2. Research questions

The outcomes provided so far seem to suggest that, unlike what was observed for innovative procurement, the effect of standard procurement is rather controversial, so putting in doubt any concrete indirect effect ascribable to the generic enlargement of market demand as well as to the peculiar features of public demand in terms of stability and magnitude, which ultimately spur investments and productive capacity. The choice made in this work in assessing the capability of PP to stimulate the innovative behavior of firms is to consider both direct and indirect effects. The choice depends on the nature of data we have access to, whose covariate of reference – procuring to the public sector – by construction includes both innovative and general procurement. Since we can neither distinguish these two types of PP nor there is a strong agreement that general procurement is not capable of positively affecting innovation (Caravella and Crespi 2021), I still find it reasonable to hypothesize that also the latter contributes to stimulating innovation and to test a comprehensive indicator of PP accordingly. Given this assumption, the research question I address in this work can be stated as follows:

1. Does having engaged in PP in the past influence firms' innovative output in the future?

Taking as reference the outcomes from the contribution previously mentioned, the logical expectation is to observe that firms in the sample

should positively react to PP activities by reporting a larger probability to introduce innovative output, although some contributions have paved the way to effects detrimental to firm performance (Chang 2017; Akcigit *et al.* 2018; Cappelletti and Giuffrida 2021). Yet, it should not be neglected that the relation is evaluated within the relevant and largely unexplored case of Italy (Caravella *et al.* 2021), which is characterized by a low performance in institutional index and innovativeness, as well as by a large heterogeneity, both at sectorial and geographical level (Giordano *et al.* 2015; Bugamelli *et al.* 2012; Bugamelli and Lotti 2018; Lasagni *et al.* 2015). Therefore, it may not be excluded a priori that the relation feels such country effects.

Taking advantage of the dataset used for the analysis, which makes available information on the share of firms' turnover ascribable to PP contracts, a further original contribution to literature may be provided by answering this further question:

2. Does the result of question 1 depend on the share of PP in firms' turnover?

This question represents the attempt to investigate an aspect which – to the best of my knowledge – has not received particular attention in the literature so far. The pretty robust effect provided for (innovative) PP has not been accompanied by a remark on how much a firm engages in PP. Hence, in this work, I aim to push a little forward the understanding of the effect of PP – in general – on innovation and how this effect may vary with firms' engagement, meant in terms of firm turnover's share ascribable to procurement contracts. Although PP is expected to enhance the innovative behavior of firms, doing too much PP may somehow slow down it. A larger resort to PP may withhold different motivations that are outside the quest for those conditions that facilitate investments in innovative projects, like easier access to credit or a reduction in development costs. Thus, the potential existence of a 'hidden face' of PP deserves to be properly investigated.

3. Data and descriptive statistics

The empirical analysis provided in this work exploits data from *Rilevazione Longitudinale Imprese e Lavoro* (RIL), a firm-level survey carried out by the *Istituto Nazionale per l'Analisi delle Politiche Pubbliche* (INAPP)[3]. Since 2005, RIL collects information on the attitude of firms regarding their labor use and the characteristics of labor demand through the computer-assisted telephone interviewing (CATI) technique. The survey covers a representative sample of partnerships and limited liabilities Italian companies that operate in the private non-agricultural sector, stratified by sector, size and geographical localisation. The sampling strategy of RIL surveys is grounded on stratified sampling with variable probability extraction in proportion to the size of the firm and uses a reference population provided by the Italian Statistical Institute in the ASIA database.

Besides its methodological solidity, a further reason behind the recourse to RIL data refers to the opportunity to choose proper control variables among a wide set of firm-related variables. Indeed, among all, RIL provides information on, for instance, the managerial structure and the employment dynamics within a firm, the type of innovation pursued by a firm, the internationalisation status, and the financial performance.

Among all the survey waves, the last two waves – that is 2015 and 2018 waves – appear of particular interest for the analysis in this work, as, for the first time in RIL, they provide information on PP. In both questionnaires (see Box 1), firms were asked whether they engage in PP during the reference period and, in case of an affirmative answer, the share of firm turnover ascribable to procuring to public administration[4]. Consequently, the information is used both to build a dichotomous regressor – called *PAproc* – by assigning a value equal to 1 if a firm is involved in procuring to public administration; and, to build a continuous regressor – *PAproc_share* – representing the weight PP contracts exert on firm total turnover (in percentage value). Unfortunately, no information is available on the object of PP, that is whether the content of the procurement is innovative or standard/regular. Besides these two main covariates, by exploiting the rich RIL dataset, I include several variables to control for firm-level characteristics. Since the information on procurement is collected from the last two waves onwards, these represent the ultimate data source for the analysis. Out of the general sample, I exclude from the analysis one-man firms in

3 INAPP is part of the Italian National Statistical System (SISTAN).

4 Only with regards to 2015 RIL survey, firms engaging in public procurement are asked to estimate the revenues from public procurement contracts.

light of their unstructured workforce. Therefore, the final sample consists of 52,088 observations from nearly 40,500 firms, whose nearly 43.50% represents the balanced panel component. The description of all variables is reported in Table 1, whereas the summary statistics in Table 2. Concerning the dependent variable of our analysis, the literature provides several ways to treat firm innovativeness, ranging from innovation inputs, such as expenditures in RandD, to innovation outputs, such as patents (Aschhoff and Sofka 2009). Data availability dictates the choice of the latter approach, as surveyed firms were asked whether they undertook product and process innovations within the three-year period prior to the survey. This information on single types of innovations, which is provided for all firms in the sample, is exploited to build a general indicator of innovation, assuming a value equal to 1 should a firm declare at least one innovation, whatsoever its kind. In our sample, nearly 46% of firms declare to have undertaken at least one innovation. Slightly larger is the share of firms that declare to have undertaken product innovations within the previous three years. When it comes to our main covariates, slightly less than one firm out of three claims to supply the public administration through pro-

Box 1. Main questions on PP in the 2015 and 2018 RIL survey waves

L12 (2015) / L10 (2018): Does the firm provides products or services to Public Administration (central, regional, provincial or local)?

1. Yes
2. No

L13a (2015) / L11 (2018): Which share of total revenues is ascribable to the sale of products or services to Public Administration?

Table 1. Description of the variables used in the analysis

Variables	Unit	Description
Innovation	Dummy	Declaring at least a product or process innovation in the previous three years - (yes=1)
Proc_Innovation	Dummy	Declaring at least a product innovation in the previous three years - (yes=1)
Prod Innovation	Dummy	Declaring at least a process innovation in the previous three years - (yes=1)
PAproc	Dummy	Procuring to PA in the previous year - (yes=1)
PAproc_sr	Share	Share of turnover from procuring to PA in the previous year
RED	Dummy	Investing in Research and Development in the previous year - (yes=1)
ICT	Dummy	Investing in Information Technology in the previous year - (yes=1)
EM	Dummy	Investing in Equipment and Machineries in the previous year - (yes=1)
Training	Dummy	Offering training activities in the previous year - (yes=1)
STRAIN	Share	Share of workers doing training in the previous year
SNPW	Share	Share of non-productive workers in the previous year
Age	Continuous - log values	Age at the survey year
Micro/small firm	Dummy	Whether the firm is micro or small (total no. of workers < 50) - (yes=1) *
Exporter	Dummy	Exporting goods/services in the previous year - (yes=1)
LabUnion	Dummy	Presence of Labor Union representation inside the firm in the previous year - (yes=1)
Group	Categorical	Belonging to a firm group in the previous year **
Industry	Categorical	ATECO 2005 sectorial taxonomy
Region	Categorical	Localisation of registered office at Region (NUTS2) level

* One-man firms are not included.
** 0 = No group affiliation; 1 = National group; 2 = Foreign group.
Source: personal elaboration on RIL data

Table 2. Data descriptives of the variables included in the analysis

Variables	No. of Obs	Full Information	No. of Firms	Full Information	Mean	St. Dev	25th pc	50th pc	75th pc
Innovation	52,088	*YES*	40,535	*YES*	0.46	0.50	0	0	1
Prod_Innovation	52,088	*YES*	40,535	*YES*	0.39	0.49	0	0	1
Proc_Innovation	52,088	*YES*	40,535	*YES*	0.34	0.47	0	0	1
PAproc	51,808	*99%*	40,535	*YES*	0.31	0.46	0	0	1
PAproc_share *	13,327	*26%*	11,242	*28%*	22.42	30.59	1.00	5.00	30.00
RED	50,967	*98%*	40,535	*YES*	0.12	0.33	0	0	0
ICT	50,967	*98%*	40,535	*YES*	0.22	0.41	0	0	0
EM	50,966	*98%*	40,535	*YES*	0.35	0.48	0	0	1
Training	52,088	*YES*	40,535	*YES*	0.56	0.50	0	1	1
STRAIN **	27,582	*53%*	22,848	*56%*	69.33	32.92	39.47	81.25	100
SNPW	52,088	*YES*	40,532	*YES*	42.63	36.67	12.50	31.25	79.17
Age (abs. values)	52,088	*YES*	40,532	*YES*	26.11	19.49	15.00	24.00	35.00
Micro/small firm	52,089	*YES*	40,533	*YES*	0.80	0.40	1	1	1
Exporter	52,088	*YES*	40,535	*YES*	0.27	0.45	0	0	1
LabUnion	52,086	*100%*	40,535	*YES*	0.22	0.41	0	0	0
No group º	52,088	*YES*	40,535	*YES*	0.86	0.34	1	1	1
National group º	52,088	*YES*	40,535	*YES*	0.13	0.33	0	0	0
Foreign group º	52,088	*YES*	40,535	*YES*	0.04	0.19	0	0	0
Total	52,088		40,535						

N.B.: Firms are the units to which statistic values refer.
* Data provided for those firms procuring to PA.
** Data provided solely for those firms with training activities.
º As firms may have changed affiliation during the reference period, the sum of means is slightly larger than 1.
Source: personal elaboration on RIL data

curement contracts. Among them, PP represents, on average, 22% of total income. Its distribution is highly rightward skewed, being its median value equal to solely 5% of total income. In other words, for half of the firms in the sample, PP represents a marginal activity to their ordinary business.

With regards to aspects related to asset-related strategy, the figures indicate that, on average, the firm propensity in investing in tangible assets is pretty low. About 35% of firms invested in acquiring productive industrial equipment and machinery. Even rarer are, within the sample, investment in intangible assets, such as those in RandD, which represents a crucial activity for successful innovation activities (Cohen and Levinthal 1990), and ICT. Respectively, only 12% and 22% of firms invested in such assets in the year prior to the survey. Much more common among firms is investment in human capital. Indeed, slightly more than half of firms set up training initiatives, which do not appear marginal in terms of employee participation: nearly seven employees out of ten were, on average, involved in formative activities. A further way to proxy an aspect related to human capital is to look at a measure of skills, proxied by the variable *SNPW* which, similar to Piva and Vivarelli (2009), represents the ratio in percentage terms between non-productive workers (such as white-collar and managers) and total employees within a firm[5], which is assessed to be equal, in the average firm, to

5 Piva and Vivarelli (2009), instead, proxy the measure of skills by recurring to the ratio between productive (blue-collar) and non-productive (white-collar) workers.

Table 3. Data descriptives of the variables included in the analysis – Comparison between groups of firms

	Firms that do not procure to PA			Firms that procure to PA			t-test
Variables	No. of Firms	Mean	St. Dev	No. of Firms	Mean	St. Dev	p > |t|
Innovation	27,861	0.44	0.50	12,674	0.50	0.50	0.0000
Prod_Innovation	27,861	0.37	0.48	12,674	0.43	0.49	0.0000
Proc_Innovation	27,861	0.34	0.47	12,674	0.36	0.48	0.5439
RED	27,861	0.11	0.32	12,674	0.13	0.34	0.0000
ICT	27,861	0.20	0.40	12,674	0.26	0.44	0.0000
EM	27,861	0.33	0.47	12,674	0.39	0.49	0.0000
Training	27,861	0.54	0.50	12,674	0.69	0.46	0.0000
STRAIN **	14,367	68.78	33.56	8,841	70.29	31.66	0.0002
SNPW	27,861	41.90	37.08	12,674	44.29	35.51	0.0000
Age (abs. values)	27,861	26.01	19.19	12,674	26.49	20.23	0.0122
Micro/small firm	27,861	0.81	0.39	12,674	0.78	0.42	0.0000
Exporter	27,861	0.31	0.46	12,674	0.20	0.40	0.0000
LabUnion	27,861	0.21	0.41	12,674	0.24	0.43	0.0000
No group º	27,861	0.85	0.36	12,674	0.85	0.36	0.1196
National group º	27,861	0.12	0.32	12,674	0.12	0.32	0.3370
Foreign group º	27,861	0.04	0.20	12,674	0.03	0.17	0.0000

N.B.: Firms are the units to which statistic values refer.
* Data provided for those firms procuring to PA.
** Data provided solely for those firms with training activities.
º As firms may have changed affiliation during the reference period, the sum of means is slightly larger than 1.
Source: personal elaboration on RIL data

43%. With respect to the degree of internationalisation, the average firm of the sample is not particularly devoted to competing in foreign markets: only 27% of firms declared to export their products. A figure that may relate to the abundance of small dimension firms in the sample[6] as well as to the low affiliation to national or multinational groups (De Toni and Nassimbeni 2001). Lastly, the *LabUnion* variable, which captures forms of employee representation, such as the Company Union Representation (RSA in Italian) and Unitary Representation Bodies (RSU), indicates a low incidence of these bodies within the sample which, by being representative of Italian firms, is, ultimately, characterized by a very large predominance of micro/small size firms as well as an adult age.

Although useful, the descriptive statistics so far mentioned do not consider possible differences between firms involved in PP and their counterparts. An issue to be taken into account, as the literature suggests that the involvement in PP may be conditional to some firm characteristics, thus making the involvement in PP not equal to all firms[7]. Therefore, Table 3 reports the same descriptive statistics regarding the previous set of firm-related characteristics for two distinct subsamples of firms. Several differences emerge from the comparison between firms involved in PP with their counterparts. A larger share of innovative firms (especially those undertaking product innovation) is found among firms involved in PP. Also, investments, training activities and bodies of employee representation are more common among those firms, whereas exporting is more practised among firms that do not supply goods and services to the PA (31% vs 20%).

4. Econometric analysis

The objective of this work is to provide new evidence

6 The median value for the variable Employment, capturing the total number of employees within a firm, indicates that more than half of the firms fall within the micro- or small-size classes.

7 This issue constitutes the reason why a propensity score matching methodology will be – later – employed to check the robustness of the econometrical analysis reported in Section 4.

on the relation between PP and firm innovativeness with the main aim to inquire whether and, if affirmative, how much the – supposedly positive – potential relation between procurement and innovation is mediated by the incidence of PP contracts on the business activity of firms. Put in other terms, to investigate whether different degrees of PP involvement correspond to different probabilities to be innovative. To this aim, I set up an empirical analysis that, thanks to the recourse to different models as well as specifications, addresses as many as possible potential biases capable to weaken the estimates as possible.

I start by performing a cross-sectional analysis on lagged variables through a simple probit model. The recourse to lagged variables permits to tackle a potential bias ascribable to a simultaneity in data. Next, I exploit the panel dimension of the dataset to limit the bias due to an omission of explanatory variables. Two approaches are followed: first, the Random Effects (RE) approach, which assumes the individual unobserved heterogeneity is uncorrelated with the independent variables (Random Effects); then, the Correlated Random Effects (CRE) approach, which, instead, allows for a share of the individual unobserved heterogeneity to be correlated with the independent variables. Eventually, I deal with the issue of selection, which is a typical concern when the impact of any public policy (whose PP is an emblematic demand-side example) is evaluated. To this purpose, after building an artificial sample of firms all similar in observable characteristics other than a specific treatment, a technique that is largely exploited in the field of industrial economics (Almus and Czarnitzki 2003; Czarnitzki and Lopes-Bento 2011), I re-run the appointed baseline model to assess its robustness in this regard.

Baseline estimates

As mentioned, the objective of the empirical analysis is to assess the relation between PP and firm innovativeness. The starting point of the analysis relies on the following econometric specification:

$$INNOVATION_{i,t} = \alpha + \beta_1 PubProc_{i,t-1} + \gamma X_{i,t-1} + u_{i,t} \quad (1.1)$$

with i (firm)=1,…,N and t (wave) = 2015, 2018

where *i* stands for firm and *t* for survey wave. As the dependent variable $INNOVATION_{i,t}$ represents the introduction of at least one innovation – whatsoever the kind – within a three-year period prior to the survey, it emerges a problem of simultaneity with the covariates, which, instead, refer to the year prior to the survey. Therefore, to mitigate the risk of simultaneity-related endogeneity, the covariates are lagged to the previous wave (that is, the 2015 RIL wave). The main regressor is represented by $PubProc_{i,t-1}$, which stands for a measure of PP performed in *t-1*; whereas $X_{i,t-1}$ includes within the model a vector of firm-related controls for a firm *i* in *t-1*, as well as information on the industrial specialisation and the regional localisation[8]. Eventually, $u_{i,t}$ represents the error term that captures the idiosyncratic component of the dependent variable.

As the dependent variable is dichotomous in nature, the equation (1.1) is estimated through the recourse to a simple probit methodology. I estimate this basic model under different model specifications, which vary in the way the main regressor is computed (Cols. 1 to 3 in Table 4). Given the nonlinear nature of probit models, Table 4 reports the average marginal effects, which represent the average change in probability when the covariate increases by one unit. To start, a simple dummy on procurement activity is included (Col. 1), which turns out to be positive and statistically significant: being active in the activity of PP is associated, on average, with an increase in the probability of innovating by 3.7 percentage points. The effect is robust to the inclusion of a variable that indicates the share of firm turnover ascribable to PP (Col. 2). The effect of this share is found to be statistically significant (yet, at a lower interval of confidence) and negative. Yet, the estimates indicate the effect is pretty small: a percentage point increase in the share of firm income ascribable to PP is associated with a reduction in the probability of innovating equal to 0.1 percentage points. It follows that PP, although its effect turns significant, does not appear as a game changer for the probability of innovating. Col. 3, instead, reports the estimates for the model specification in which the

8 Although related indication is reported in Table 1, it is useful to remind that the original dataset was rearranged in order to compile a coherent industrial indicator linked to the ATECO 2005 sectorial taxonomy made of 16 categories. Such an information on industrial specialisation was later matched with information on localisation at regional level (NUTS 2 classification). In this way it was possible to exploit the newly arranged categorical variables to control for heterogeneity in both regional and sectorial level.

Table 4. Average Marginal Effects outcomes – Procurement to PA and Innovation; firm-level controls; all covariates are one period lagged

Y = Innovation	(1) Dummy	(2) Dummy + Share	(3) Categories of Procurement shares
PAproc *	0.037***	0.039***	
	(0.010)	(0.012)	
PAproc_sr		-0.001*	
		(0.000)	
PAproc_sr: Up to 5% **			0.033**
			(0.013)
PAproc_sr: From 5% to 20% **			0.051**
			(0.022)
PAproc_sr: From 20% to 40% **			0.059*
			(0.034)
PAproc_sr: From 40% to 60% **			-0.043
			(0.035)
PAproc_sr: From 60% to 80% **			-0.027
			(0.036)
PAproc_sr: Over 80% **			0.006
			(0.034)
RED *	0.136***	0.136***	0.137***
	(0.016)	(0.016)	(0.016)
ICT *	0.030**	0.031**	0.031**
	(0.012)	(0.013)	(0.013)
EM *	0.116***	0.120***	0.120***
	(0.010)	(0.011)	(0.011)
STRAIN	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
SNPW	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Age (log)	0.007	0.009	0.008
	(0.007)	(0.007)	(0.007)
Micro/small firm *	-0.065***	-0.061***	-0.061***
	(0.013)	(0.013)	(0.013)
Exporter *	0.117***	0.118***	0.118***
	(0.011)	(0.011)	(0.011)
LabUnion *	-0.005	-0.006	-0.006
	(0.012)	(0.013)	(0.013)
National group ***	-0.022	-0.023	-0.024
	(0.015)	(0.015)	(0.015)
Foreign group ***	0.013	0.022	0.022
	(0.027)	(0.028)	(0.028)
Industry FEs	Yes	Yes	Yes
Region FEs	Yes	Yes	Yes
No. of Observations	10,927	10,453	10,453

Coefficients are shown (standard errors in parentheses).
Significance level: *10% **5% ***1%.
*Dummy variables: (Yes).
**Reference class: No procurement to PA.
***Reference class: No affiliation to a group.

Source: personal elaboration on RIL data

involvement in PP is captured through a categorical variable, whose values are fixed at some quotas. Grouping procurement shares into a categorical variable, to better match the high asymmetry observed in procurement share, provides further hints of the magnitude of the effect associated with PP. Compared to firms noninvolved in PP, firms with up to 5% of total revenues from procurement contracts report a 3.3 percentage point higher probability to be innovative. The effect is even larger in the following two subclasses indicating, respectively, a procurement share on total revenues ranging between 5% and 20%; and between 20% and 40%. In the former case, the increase in the probability of innovating amounts to 5.1 percentage points; whereas, 5.9 percentage points in the latter case. The outcomes provide evidence of a significant and positive impact of PP yet one that is limited to a scenario in which PP represents up to 40% of the total revenues of a firm. When PP activities exceed such a threshold, no significant effects on the probability to innovate are found.

With regards to the set of firm-related characteristics, the coefficients' estimates match the expectations. Investments in both intangible and tangible assets (RandD, ICT, EandM) positively relate to firms' innovativeness, in line with previous evidence by Hall *et al.* (2012) and Montresor and Vezzani (2016). Indeed, a firm that undertakes those types of investment enhances the probability of innovating by, respectively, 14 and 12 percentage points. As for human capital, considered an essential part of innovation (Lee *et al.* 2010), spurring its accumulation through the recourse to training activities or a larger share of employees out of – strictly speaking – productive phases, is associated with a positive increment in the probability of innovating. A result aligned with previous contributions inquiring about the role played by human capital to enhance firms' innovativeness (Dakhli and De Clercq 2004; Alpkan *et al.* 2010; Faems and Subramanian 2013; McGuirk *et al.* 2015). Two further characteristics are found to be positively correlated to innovation: attitude to export products and size. About the former, there is a large consensus on a positive relationship between innovation and export intensity (Roper and Love 2002; Pla-Barber and Alegre 2007; Fassio 2018). Whereas, when it comes to size, its relation to innovation is largely disputed and controversial (see Fang *et al.* 2021 for a review). SNPW, instead, is not found to exert an appreciable effect. Indeed, a one percentage point increase in the share of non-productive workers (which should also include the personnel involved in developing innovations) is associated with an increase in the probability of innovating by solely 0.1 percentage points. Lastly, when it comes to age, it is not found to be significant in any of the model specifications.

Once checked that even firm-related variables behave as expected, it may be put forward that this first evidence, although far from being exhaustive, does provide support within the Italian panorama of a positive association, although small, between PP and innovativeness as already acknowledged in the literature. Concerning the original-related aspect of this work, some hints of the likewise importance of procurement weight on business activity are detected. The positive and statistically significant correlation limited to lower shares of PP may be thought – with due precaution – to go in the direction of the hypothesis I advanced in terms of resources diversion from activities addressing innovation, that is a larger involvement in procurement may lower the innovative capability of firms. A result that is partially – performance being measured differently here – in line with the evidence provided in Chang (2017).

Being Italy characterized by a larger firm size fragmentation with respect to its main European partners as well as a firm preference towards developing process-related innovations (Bugamelli *et al.* 2012), the analysis can be further extended. As RIL surveys distinguish product from process-related innovation, there is, therefore, an opportunity to test the robustness of the outcomes to a change in the dependent variable. To this aim, the chosen baseline specification (Col. 3 in Table 4) is once more regressed on two new dependent variables: the first one stands for – solely – the introduction of product-related innovations; the second one, conversely, stands for – solely – process-related innovations. The outcomes of the regressions as well as the average marginal effects for each covariate are reported in Table 5. The estimates are made by employing a bivariate probit regression due to the presence of firms that simultaneously conduct both product and process innovation. Indeed, a rho equal to 0.8 supports the argument not to estimate separately the probit models based on each type of innovation at time.

Table 5. Bivariate probit model – Regression & AME outcomes on Product and Process Innovation; firm-level controls; all covariates are one period lagged

	Y = Prod_Innovation	Y = Proc_Innovation
	Average Marginal Effects	Average Marginal Effects
PAproc_sr: Up to 5% **	0.035***	0.010
	(0.013)	(0.012)
PAproc_sr: From 5% to 20% **	0.050**	0.030
	(0.022)	(0.021)
PAproc_sr: From 20% to 40% **	0.066*	0.026
	(0.034)	(0.032)
PAproc_sr: From 40% to 60% **	-0.025	-0.053
	(0.034)	(0.033)
PAproc_sr: From 60% to 80% **	-0.007	-0.034
	(0.036)	(0.034)
PAproc_sr: Over 80% **	-0.003	0.001
	(0.033)	(0.033)
Firm related controls	Yes	Yes
Industry FEs	Yes	Yes
Region FEs	Yes	Yes
No. of Observations	10,453	10,453
Rho	0.8023	
Prob > chi2	0.0000	

Coefficients are shown (standard errors in parentheses).
Significance level: *10% **5% ***1%.

N.B.: Shares are expressed in percentage.
**Reference class: No procurement to PA.

Source: personal elaboration on RIL data

What emerges from the estimates is a clear predominance of the product-related innovation in driving the previous outcomes. Indeed, PP is associated to a significant increase in the probability of innovating solely when it comes to develop new products and, as before, should the incidence of PP on firm's turnover is below the threshold of 40%. This predominance drives the magnitude of the AME estimates in each subclass of procurement share to remain pretty stable in this model specification. For instance, a PP incidence on turnover between 20 and 40% is associated to an increase in the probability of innovating (products) by 6.6 percentage points, versus 5.9 percentage points in the same subclass in the 'general' specification. An interpretation of this result may be advanced in light of the transmission channels debated in the literature. Indeed, it may be reasonable to assume that product innovations are those that might benefit the most from the PP if we refer to the following assumption. That is, firms may not find it particularly useful to invest resources to 'win' the opportunity to exploit a niche environment in which to develop – as the main goal – a production process. Rather, it sounds more likely for firms to exploit the opportunity to come up with innovative products that may find a quicker return in the market. In addition, this result does not seem to support the issue of complementarity between process and product innovations, that is implementing new products might require a parallel innovation in the way to produce them (Freeman and Soete 1997; Swann 2009; Doran 2012).

In a similar manner, one may wonder whether the effect of PP varies not solely in terms of which type of innovation a firm pursues, but even in terms of other structural characteristics of the firm, such as its size. Therefore, Table 6 replicates the estimates of the previous model specifications for two different subsamples: that of micro/small firms, which include firms with up to 49 employees (with the exclusion of individual firms); and that of medium/large firms, which include firms with more than 50

Table 6. Average Marginal Effects outcomes – Procurement to PA and Innovation; firm-level controls; all covariates are one period lagged

Y = Innovation	MICRO / SMALL FIRMS		MEDIUM / LARGE FIRMS	
	Dummy + Share	Categories of Procurement shares	Dummy + Share	Categories of Procurement shares
PAproc *	0.043***		0.035	
	(0.014)		(0.025)	
PAproc_sr	-0.000		-0.001**	
	(0.000)		(0.001)	
PAproc_sr: Up to 5% **		0.038**		0.036
		(0.015)		(0.026)
PAproc_sr: From 5% to 20% **		0.058**		0.038
		(0.025)		(0.044)
PAproc_sr: From 20% to 40% **		0.095**		-0.048
		(0.040)		(0.065)
PAproc_sr: From 40% to 60% **		-0.059		-0.037
		(0.040)		(0.074)
PAproc_sr: From 60% to 80% **		0.029		-0.147**
		(0.043)		(0.074)
PAproc_sr: Over 80% **		0.053		-0.045
		(0.043)		(0.057)
RED *	0.151***	0.152***	0.109***	0.108***
	(0.023)	(0.023)	(0.022)	(0.022)
ICT *	0.051***	0.051***	-0.002	-0.003
	(0.016)	(0.016)	(0.021)	(0.021)
EM *	0.126***	0.126***	0.098***	0.097***
	(0.012)	(0.012)	(0.021)	(0.021)
STRAIN	0.001***	0.001***	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
SNPW	0.000**	0.000**	0.001***	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Age (log)	0.006	0.006	0.014	0.015
	(0.009)	(0.009)	(0.014)	(0.014)
Exporter *	0.122***	0.122***	0.081***	0.080***
	(0.013)	(0.013)	(0.024)	(0.024)
LabUnion *	-0.011	-0.011	-0.010	-0.010
	(0.017)	(0.017)	(0.019)	(0.019)
National group ***	-0.030	-0.031	-0.017	-0.017
	(0.022)	(0.021)	(0.021)	(0.021)
Foreign group ***	0.050	0.049	0.007	0.007
	(0.052)	(0.052)	(0.032)	(0.032)
Industry FEs	Yes	Yes	Yes	Yes
Region FEs	Yes	Yes	Yes	Yes
No. of Observations	7,881	7,881	2,572	2,572

Coefficients are shown (standard errors in parentheses).
Significance level: *10% **5% ***1%.
*Dummy variables: (Yes).
**Reference class: No procurement to PA.
***Reference class: No affiliation to a group.

Source: personal elaboration on RIL data

employees. Interestingly, the figures in Table 6 seem to suggest that PP correlates positively to innovation only in presence of micro/small firms. For instance, the probability of innovating for a micro/small firm engaged in PP (with an incidence between 5 and 20% on turnover) is 6 percentage points larger than that observed in a similar firm that is not involved in PP. The effect found here mirrors that previously described: PP positively (and significantly) correlates to innovation only when the incidence of PP does not overcome the threshold of 40%. That is when PP solely represents an ancillary activity for a firm's business rather than its core. Whereas, when we consider medium/large firms, PP does not seem to significantly correlate with the probability of innovating.

This latter result may not be negligible within the Italian context from a policy perspective, as it provides a hint of PP as an effective policy to target the development of specific types of firms. Indeed, the result that sees micro/small firms reactive to PP in terms of PP may confirm some of the benefits the literature associates with the engagement with the public sector. For instance, small firms, which may suffer from financial constraints, may exploit the cash flow resulting from government demand to reduce the external financial premium (Hebous and Zimmermann 2016), also in presence of improved credibility (Lee 2021), to enhance the credit access, thus impacting on the number of additional resources a firm can collect to address innovative projects.

Being aware of the scope of this latter clause, it is mandatory to strengthen it by tackling further biases that may have an impact on the estimates. Therefore, in the next section, the robustness of the estimates is checked by means of a panel data analysis in order to reduce bias from omitted variables.

Panel data regressions

The analysis that has been conducted so far is based on cross-sectional lagged data to null the risk of endogeneity due to simultaneity between the dependent variable and its covariates, as they refer to time periods with different lengths. Even if such a risk – and limit – is acknowledged to potentially occur, in this section I introduce a different econometric exercise. That is, by using both the most recent RIL waves that provide information on PP, I exploit the potentiality of a panel structure, though short, in data to control for within (firms) unobserved variability. Hence, such an exercise is to be intended as a further robustness check for previous estimates in the perspective of containing even more cogently the bias due to omitted variable, even if – again, it is useful to remind it – laying the exercise open to endogeneity due to simultaneity.

To provide even more solid outcomes, two different estimation strategies are performed and compared. To start, Random Effects estimations, which assume that firm-level effects do not correlate with the set of chosen covariates. Yet, the hypothesis of not correlation between individual effects and other regressors looks pretty demanding. Therefore, in the second strategy the Correlated Random Effects (CRE) approach is adopted to relax the random effects' restrictive assumption. Such an approach is based on the assumption that, conversely to before, a share of the individual effects may correlate to the set of regressors (Mundlak 1978). Following Antonakis *et al.* (2019), the CRE models include the cluster means of the x_{it} regressors. The advantage of choosing a CRE model lies in its capability to unify RE models with fixed effects (FE) models. Indeed Antonakis *et al.* (2019) argue that, besides overcoming the previously cited and, often, unrealistic assumption of RE models, CRE approach, unlike FE models, permits to model effects of variables that are constant within cluster. Therefore, such an approach should return coefficients that are identified solely through the within-firm variability, so equivalent to what takes place in a FE model. Coefficients that take into account the endogeneity due to omitted variables due to unobserved heterogeneity.

Table 7 reports estimates for the baseline model specification. Two versions are reported: the first one assumes random effects, whereas the second one assumes correlated random effects. For a matter of conciseness, solely the average marginal effect values are shown. Before commenting the estimates, a preliminary step regards which approach should be preferred. Generally speaking, CRE approach appears appealing by virtue of the addition of cluster means that permit to relax the restrictive assumption regarding the uncorrelation between the random part of the model and the regressors (Antonakis *et al.* 2019).

The addition of cluster means (also known as Mundlak terms) provides an additional advantage in choosing the CRE approach, as it permits to identify within-effects (represented by the regressors' estimates) as well as contextual-effects (represented by the cluster means' estimates), whose sum provides for the between-effect[9]. The contextual effects may be used to preliminary test the correlation between regressors, in particular, the variables capturing PP, and other firm-related unobserved characteristics that affect innovation. Since the estimates of the Mundlak terms (not displayed in Table 7) are not statistically significant, theoretically RE approach should be preferred over CRE approach. Yet, it may not be neglected that CRE estimates are reasonably driven by the very short panel dimension – based on two periods – that makes the introduction of cluster means pretty demanding to properly estimate the model, as little variation among individuals is allowed. Whether it is more suitable to adopt the RE approach or not, it is fairly reassuring that the estimates for the AME of the covariates capturing involvement in PP overlap whatsoever the estimation strategies. Proceeding with a comparison between panel estimates and (previous) cross-sectional lagged estimates, a few differences emerge. The panel estimates show an inverse u-shaped relation between the incidence of PP and the probability of innovation. The associated probability of innovating is the highest when PP accounts for between 20 and 40% of the firm turnover, then, after this threshold, it reduces in magnitude. Yet, unlike what has been previously observed through a cross-sectional data analysis, higher incidences of PP on firm turnover are still positive and statistically significant.

The divergence between cross-sectional and panel estimates may not necessarily be regarded as conflicting since both estimates provide hints about the emergence of negative aspects once the incidence of procurement share on turnover is above a certain threshold. In the case of cross-sectional estimates, we may deduce the positive aspects of PP appear counterbalanced by the negative ones, putting on an equal footing non-procurement and highly procurement firms. A picture that winks at the idea of a firm that, by being heavily dependent on public demand, decides to refrain from investing in innovation to compete in the market (Chang 2017) or, rather, to invest its resources in alternative activities that do not address innovation, like feeding political ties, which are as well relevant to award PP contract (Akcigit *et al.* 2018). Whereas, in the case of panel estimates, although we do not observe a full counterbalance between positive and negative effects, we get clues of a beneficial impact of PP that is eroded by a larger incidence of procurement share on turnover. In this sense, resource diversion due to sizeable involvement may sound like a potential explanation to interpret such an 'erosion'.

Before proceeding with further robustness checks, a few more words on the difference in estimates' magnitude between the panel and cross-sectional data. We cannot neglect that the quite larger numerosity in observations exploited by the panel data analysis as well as its possibility to control for the within-firms unobserved variability might have fed the discrepancies in estimates. An issue that may be properly tackled in further developments in presence of data spanning longer periods, which would enable the use of lagged variables within the context of a panel analysis, thus tackling within the same estimation strategy both bias due to simultaneity and omitted variable at the same time.

Propensity score matching

An issue of concern for those inquiring about the role played by public policies in explaining firms' performance is the selection problem. An issue that should not be neglected irrespective of whether the policy intervention is supply- or demand-oriented. Indeed, even the award of a PP contract may not be neutral both on the side of firms and on the side of contracting authorities (Ghisetti 2017; Ferraz *et al.* 2015).

To start, firms with some specific characteristics that imply capability advantages may be provided with higher chances to be engaged in PP (Aerts and Schmidt 2008; Caravella and Crespi 2021). For instance, larger firms may be endowed with specific staff devoted to managing PP tenders or their information network much more effectively. In other words, firms may self-select themselves

9 As reported in Antonakis *et al.* (2019), in order to get between-individual effects (represented by the coefficient of cluster means), the explanatory variable should be cluster-mean centered. In the proposed specifications, the explanatory variable is included as such, therefore the coefficients of cluster means identify the contextual effect. I remind that the contextual effect indicates "*how the mean of the characteristic in the context affects individual level outcomes*" (Antonakis *et al.* 2019, 14).

Table 7. Average Marginal Effects – Procurement to PA and Innovation; firm-level controls; Panel data version

	Model 3: Categories of Shares	
	with Random Effects	with Correlated Random Effects
PAproc_sr: Up to 5%**	0.073***	0.073***
	(0.006)	(0.006)
PAproc_sr: From 5% to 20%**	0.087***	0.086***
	(0.009)	(0.009)
PAproc_sr: From 20% to 40%**	0.108***	0.105***
	(0.014)	(0.014)
PAproc_sr: From 40% to 60%**	0.045***	0.045***
	(0.017)	(0.017)
PAproc_sr: From 60% to 80%**	0.042***	0.042***
	(0.015)	(0.015)
PAproc_sr: Over 80%**	0.032**	0.032**
	(0.014)	(0.014)
RED*	0.224***	0.125***
	(0.008)	(0.015)
ICT*	0.085***	0.048***
	(0.006)	(0.012)
EM*	0.157***	0.100***
	(0.005)	(0.010)
STRAIN	0.001***	0.001***
	(0.000)	(0.000)
SNPW	0.000***	0.000
	(0.000)	(0.000)
Age (log)	-0.013***	-0.042
	(0.003)	(0.036)
Micro/small firm*	-0.007	0.015
	(0.006)	(0.027)
Exporter*	0.161***	0.073***
	(0.005)	(0.015)
LabUnion*	0.004	0.009
	(0.006)	(0.016)
National group***	0.007	0.029
	(0.007)	(0.019)
Foreign group***	0.010	-0.044
	(0.013)	(0.047)
Industry FEs	Yes	Yes
Region FEs	Yes	Yes
Year FEs	Yes	Yes
Mundlak terms	No	Yes
No. of Observations	47,751	47,751
No. of Firms	37,787	37,787

Coefficients are shown (standard errors in parentheses).
Significance level: *10% **5% ***1%.

N.B.: Shares are expressed in percentage.
*Dummy variables: (Yes).
**Reference class: No procurement to PA.
***Reference class: No affiliation to a group.

Source: personal elaboration on RIL data

to supply the public market (Caravella and Crespi 2021). Likewise, contracting authorities may favor those firms that are reputed to be perform better than others in order to increment the probability of success of their intervention (Almus and Czarnitiski 2003), leading to the "picking the winner" bias (Cantner and Kösters 2012).

Therefore, as the access to PP granted to firms may be – intentionally or not – unequal, the sample of procuring firms in our dataset may not be randomly selected from the entire population. This has the power to weaken the outcomes previously reported, because the simple comparison of characteristics between procuring firms and their counterparts cannot reveal the direction of causality between procuring (as well as other firm's characteristics) and innovation output (Serti and Tomasi 2008). Nevertheless, some reassuring arguments may be provided in this respect by implementing a propensity score matching technique (Rosenbaum and Rubin 1983), which is largely used when a selection problem arises. The basic idea of a matching approach is to find a group of non-treated individuals – in this case firms that do not engage in PP – that is as similar as possible to the group of treated individuals in terms of relevant pre-treatment observable characteristics and, later, to use this group as a substitute for the non-observable counterfactual group (Caliendo and Kopeinig 2008; Imbens 2000). In this way, the remaining differences in the outcome variable between both groups are then attributed to the treatment (Heckman *et al.* 1997). In other words, this methodology permits to estimate the average treatment effect on the treated (ATT), that is the average effect engaging in PP exerts on innovation output for those firms that do procure to the public sector. In order to succeed in such a methodology, two requirements need to be satisfied[10]: the conditional independence assumption (CIA) and the common support condition (CSC). CIA implies that the assignment to treatment is independent of the outcome, conditional on a set of observable covariates. In other words, it requires all the systematic differences between treated and untreated individuals to be removed through the observable variables used as covariates (Caravella and Crespi 2021). Without going too deep into the methodology, since an exact matching on observable characteristics is difficult to implement, Rosenbaum and Rubin (1983) demonstrate the possibility to build a single scalar index capable to condense the vector of relevant covariates. This scalar index, called propensity score, measures the probability of being treated given the relevant covariates. What makes the propensity score particularly useful is that at a given value of propensity score, receiving the treatment should result from a random process and so both treated and control individuals should be on average observationally identical (Guerzoni and Raiteri 2015). CSC implies, instead, that the probability of receiving treatment for each possible value of the vector of covariates is strictly within the unit interval, that is the vector of covariates is not by itself capable to predict perfectly whether an individual will receive treatment or not (Guerzoni and Raiteri 2015). In other words, CSC requires that for each treated observation a similar control can be found. Satisfying both CIA and CSC permits propensity score matching to produce unbiased estimates of the average treatment effect considering the difference in outcomes over the common support, weighted by the propensity score of individuals (Caliendo and Kopeinig 2008).

The first step for the application of propensity score matching is the selection of those variables affecting the likelihood to be treated, in our case procuring to the public sector. According to Caliendo and Kopeinig (2008, 39), "*only variables that influence simultaneously the participation decision and the outcome variable should be included.* [In addition] O*nly variables that are unaffected by participation should be included in the model. To ensure this, variables should either be fixed over time or measured before participation*". Following this argument, to be totally certain the variables are unaffected by treatment, the analysis should refer to data prior to the 2015 RIL survey. Yet, referring to preceding data has its own drawbacks. First, the 2010 RIL survey does not include any information about firms' involvement in PP. This does not inform with certainty whether the survey firms were (at that time) already affected by the treatment (that

10 For a more extensive insight into propensity score matching application, see Serti and Tomasi (2008), Cerulli (2015) and Guerzoni and Raiteri (2015).

is, procuring) or not. Second, the sample numerosity on which to base the estimations would appear dramatically reduced, as a balanced panel of firms surveyed in all three waves must be employed[11]. In valuing pros and cons, I opted to calculate the propensity scores by referring to treatment and covariates from the same survey wave, believing it is little plausible that PP might be so quick to affect within the same year decisions about investments (*i.e.*, in RandD), operations (*i.e.*, export), hiring and training of personnel. Conscious that, in any case, this places a limitation to the validity of the estimates, the following equation represents the way to estimate through a probit model the propensity scores:

$$PAproc_{i,2015} = \alpha + \beta_1 RED_{i,2015} + \beta_2 ICT_{i,2015} + \beta_3 EandM_{i,2015} + \beta_4 STRAIN_{i,2015} + \beta_5 SNPW_{i,2015} + \beta_6 EXPORT_{i,2015} + \beta_7 LABUNION_{i,2015} + \beta_8 GROUP_{i,2015} + \beta_9 SIZE_{i,2015} + \beta_{10} AGE_{i,2015} + \beta_{11} INDUSTRY_{i,2015} + \beta_{12} REGION_{i,2015} + u_{i,t}$$

where the dependent variable is a dummy equal to one for firms procuring to the public sector in 2015; whereas the covariates of each firm *i* refer to values in 2015. The set of chosen firm-related covariates mirrors the same set used in the previous estimations.

After retrieving the propensity scores from the probit estimation, I proceed with the non-parametric matching[12]. Several matching methods can be employed. The most intuitive matching algorithm is the one-to-one nearest neighbor method, consisting of searching for the control with the closest propensity score. The literature has suggested for such a method the use of non-replacement, that is, once a treated case is matched to one nontreated case, both cases are removed from the pool (Guo and Fraser 2014). To assess the matching quality, Table 8 reports the tests on the equality of means for both unmatched and matched samples. As it is reported by the outcomes in the table, the one-to-one nearest neighbor matching provides a sample of firms that will not be – in the future – engage in PP, yet similar in observable characteristics to those that are awarded PP contracts. This new similarity in – artificial – samples is attested by several tests. To start, as suggested in Rosenbaum and Rubin (1983), a proper rule of thumb to consider the matching procedure successful is provided by the reduction in the mean standardized bias below the 5% threshold after matching. As shown in Table 8, all covariates fell within this threshold, even two additional variables that were not used to estimate the propensity scores, namely the recourse to second-level wage bargaining and the share of managers and mid-managers to the total of employees. Table 8 reports further tests for assessing the quality of the pairing. According to Sianesi (2004), proof of good matching emerges when the pseudo-R2 on the matched sample is lower than in the unmatched case, as this implies that treated and untreated units are very similar to each other. Additionally, as in Ghisetti (2017), looking at the log-likelihood ratio tests on differences in covariates, the hypothesis of joint insignificance before the matching is rejected, whereas it is not after the matching. Likewise, the quality of the matching may be shown also resorting to a graphical analysis of the propensity score density distribution, in both the treated and the control group (Caliendo and Kopeinig 2008). Figure 1 confirms the validity of the matching procedure given the significant improvement in similarity between treated and control distributions after the matching.

Once firms are matched, it is possible to run the previous set of regression, following the baseline specification. The estimates included in Table 9 compare the subsample of micro/small firms with that of medium/large firms. The AME for the subsamples is reported before and after the matching procedure to facilitate the comparison with previous estimates (previously reported in Table 6) based on the unmatched sample. The table provides an indication of estimates that are robust to the problem of self-selection, clearly conditional to the limitation I declared in building the matched sample, which, in any case, satisfies the requirements for a good match. Indeed, regarding the covariates capturing the PP involvement, there is substantial stability in sign, significance, and magnitude, the latter being slightly lower. Micro/small firms involved in PP with an incidence of turnover up to 5% report an increase in the probability of innovating equal to 2.9 percent-

11 This is because 2010 RIL survey would provide the weights to match the treated and the untreated samples, whereas 2015 RIL survey would provide the covariates on which to base the regressions. Lastly, 2018 RIL survey provides the information on innovation.

12 The matching has been performed through the STATA routine *psmatch2*, developed by Leuven and Sianesi (2003).

Table 8. Propensity score matching – Tests on the equality of means in the two subsamples of firms (unmatched and matched)

Firm characteristics used to estimate the propensity score*	Unmatched sample				Matched sample			
	Treated (1)	Control (2)	%bias (3)	t-test p > |t| (4)	Treated (5)	Control (6)	%bias (7)	t-test p > |t| (8)
RED	0.108	0.090	6.0	0.000	0.108	0.104	1.3	0.440
ICT	0.211	0.174	9.5	0.000	0.210	0.209	0.1	0.934
EM	0.323	0.292	6.7	0.000	0.323	0.308	3.4	0.049
STRAIN	41.954	30.234	28.5	0.000	41.858	41.917	-0.1	0.935
SNPW	44.031	41.806	6.1	0.000	43.764	44.682	-2.5	0.145
Exporter	0.174	0.294	-28.5	0.000	0.177	0.189	-2.9	0.069
LabUnion	0.229	0.202	6.6	0.951	0.228	0.216	3.1	0.072
National group	0.107	0.107	0.1	0.006	0.106	0.107	-0.3	0.847
Foreign group	0.028	0.034	-3.9	0.000	0.027	0.024	1.4	0.358
Employment (log)	2.759	2.477	17.8	0.000	2.781	2.731	3.2	0.058
Age (log)	3.142	3.111	4.9	0.000	3.150	3.140	1.6	0.337
Additional firm characteristics								
II Level wage bargaining	0.110	0.102	2.4	0.085	0.107	0.109	-0.7	0.661
SMMAN **	4.036	3.711	3.0	0.032	3.983	3.961	0.2	0.907

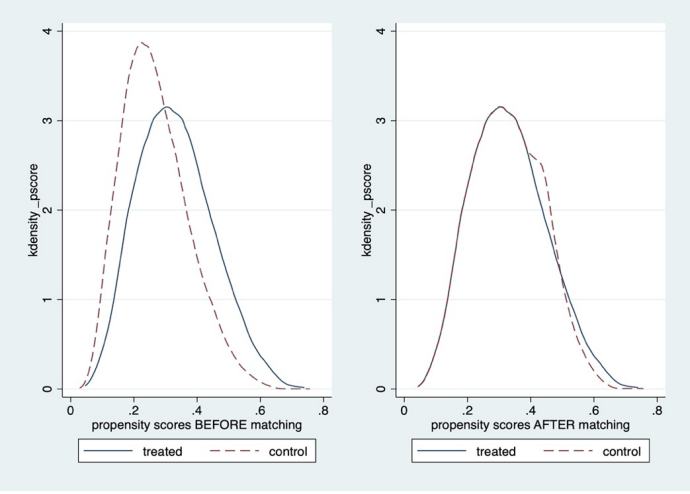
Sample	Pseudo R2	LR test: p-value:
Unmatched	0.042	0.000
Matched	0.001	0.078

N.B.: Procuring to PA (in the 2015 RIL wave) represents the treatment.
* All the variables refer to the 2015 RIL wave.
** SMMAN indicates the share of mid-managers and managers within a firm.

Cols. (1) and (2) show the average values for the vector of firm characteristics for the groups of firms that, in the future, procure to PA versus those that do not in the unmatched (original) sample. Cols. (5) and (6) show the same figures for the two groups of firms in the matched sample. Cols. (3) and (7) show the standardized percentage bias for, respectively, unmatched and matched sample. Cols. (4) and (8) show the p-value of the statistical tests for significant differences in means in each covariate, between the two groups of firms.

Source: personal elaboration on RIL data

Figure 1. Propensity score distribution for treated and control groups before and after the matching (Single nearest neighbor matching with no replacement)



Source: personal elaboration on RIL data

Table 9. Average Marginal Effects outcomes – Procurement to PA and Innovation (Matched sample vs Unmatched Sample); firm-level controls; all covariates are one period lagged

Y = Innovation	MICRO / SMALL FIRMS		MEDIUM / LARGE FIRMS	
	Matched Sample	Unmatched Sample	Matched Sample	Unmatched Sample
PAproc_sr: Up to 5%**	0.029*	0.038**	0.060**	0.036
	(0.017)	(0.015)	(0.030)	(0.026)
PAproc_sr: From 5% to 20%**	0.051*	0.058**	0.051	0.038
	(0.027)	(0.025)	(0.048)	(0.044)
PAproc_sr: From 20% to 40%**	0.086**	0.095**	-0.049	-0.048
	(0.041)	(0.040)	(0.066)	(0.065)
PAproc_sr: From 40% to 60%**	-0.062	-0.059	-0.035	-0.037
	(0.040)	(0.040)	(0.077)	(0.074)
PAproc_sr: From 60% to 80%**	0.026	0.029	-0.161**	-0.147**
	(0.044)	(0.043)	(0.071)	(0.074)
PAproc_sr: Over 80%**	0.048	0.053	-0.041	-0.045
	(0.044)	(0.043)	(0.057)	(0.057)
RED*	0.136***	0.152***	0.100***	0.108***
	(0.028)	(0.023)	(0.030)	(0.022)
ICT*	0.052***	0.051***	0.017	-0.003
	(0.020)	(0.016)	(0.028)	(0.021)
EM*	0.123***	0.126***	0.101***	0.097***
	(0.017)	(0.012)	(0.027)	(0.021)
STRAIN	0.001***	0.001***	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
SNPW	0.000*	0.000**	0.000	0.001**
	(0.000)	(0.000)	(0.000)	(0.000)
Age (log)	0.006	0.006	0.033*	0.015
	(0.012)	(0.009)	(0.019)	(0.014)
Exporter*	0.114***	0.122***	0.074**	0.080***
	(0.021)	(0.013)	(0.032)	(0.024)
LabUnion*	-0.030	-0.011	0.013	-0.010
	(0.022)	(0.017)	(0.025)	(0.019)
National group***	-0.002	-0.031	-0.003	-0.017
	(0.031)	(0.021)	(0.028)	(0.021)
Foreign group***	0.116	0.049	0.048	0.007
	(0.094)	(0.052)	(0.049)	(0.032)
Industry FEs	Yes	Yes	Yes	Yes
Region FEs	Yes	Yes	Yes	Yes
No. of Observations	4,307	7,881	1,503	2,572

Coefficients are shown (Standard errors in parentheses).
Significance level: *10% - **5% - ***1%.
*Dummy variables: (Yes).
**Reference class: No procurement to PA.
***Reference class: No affiliation to a group.

Source: personal elaboration on RIL data

age points (vs. 3.8 percentage points in the unmatched sample). For firms of this size, the increase in the associated probability of innovating is observed also for higher incidences of PP on turnover, being equal to 5.1 and 8.6 percentage points for, respectively, the categories 5-20% and 20-40%. The difference between micro/small firms and medium/large firms remains also in the matched samples, although when the incidence is limited to up 5%, an increase in the probability of innovating is reported even by medium/large firms (6 percentage points), unlike what observed in the unmatched sample. In other words, also when the self-selection bias is taken into account, micro/small firms seem to be the ones that can benefit the most from PP contracts to enhance their probability of innovating, even if, in medium/large firms, a small involvement in PP is now associated to an increase in the probability of innovation. In addition, the same persistence and coherence are, generally, found in the remaining firm-related variables. Clearly, I acknowledge these estimates on a matched sample are not able to provide clear-cut results that are fully unaffected by self-selection bias, being this exercise conceived as an additional robustness check. Yet, in the lack of similar attempts in the related literature, they represent a good starting point for future developments in order to conduct more elaborated and precise estimations and more accurately avoid bias due to self-selection.

Conclusion

The aim of this work is to investigate the effect procuring to the public sector exerts on firms' innovative output. Although there is growing literature regarding the potential impact of PP on innovation, the empirical evidence is not strongly consolidated. Moreover, to the best of my knowledge, no attention has been paid with regards to how the effect on firms' innovative output varies with the *amount* of PP a firm is engaged in. This works tries to fill the gap.

Using data from the most recent employer-employee RIL surveys I test whether procurement firms report a larger propensity of innovating in comparison to counterparts that exclusively target private customers. To this end, I apply several econometric strategies to tackle different sources of bias and so to strengthen the robustness of the outcomes. The results suggest that even in a country with a large polarisation in firm performance like Italy, procuring to the public sector is found to be associated with an increase in the probability of innovating. Yet, this result takes place only with reference to micro/small firms and when products are the target of firms' innovativeness. Therefore, when it comes to spurring innovativeness, PP seems to act like a specific- rather than a general-purpose policy suiting all scenarios and contexts. Indeed, micro/small firms, may exploit PP contracts to lower their financial constraints or improve their reputation/credibility, ultimately collecting more resources to address innovative projects. As Italy is characterized predominantly by micro/small firms, PP may represent an effective instrument for policy makers to refer to. Yet, on the other side, being the positive correlation driven by product-related innovation, it cannot be neglected that PP may not exert its full effectiveness, as the Italian scenario is generally characterized by firms that favor process-related innovations (Bugamelli *et al.* 2012). Therefore, an effective developing policy through PP may call policymakers to adopt some 'customisations' before implementation, for instance in terms of awarding criteria and bidders' selection.

Concerning the original-related aspect of the work, I find that the positive and statistically significant correlation between PP and innovation is limited to lower shares of PP, a point that may cautiously support the hypothesis that a larger involvement in procurement may be detrimental to the innovative capability of firms or be a signal of a different survival strategy that refrains from competing in the market (Chang 2017; Akcigit *et al.* 2018; Cappelletti and Giuffrida 2021).

Certainly, several limitations in this work should be kept in mind. To start, despite its rich set of firm-related information, RIL does not distinguish between innovative procurement and general procurement. Therefore, the approach I follow should be framed within the general idea that all PP may somehow be conducive to innovativeness. Yet, as Italy does not display a large diffusion in innovative PP (Petrella 2013), it may be reasonably assumed that – at least – a considerable part of the PP signalled by sampled firms reflects regular PP that, ultimately, drives the positive correlation between PP and innovation. A further limitation regards the interaction between PP and other forms of public interventions that may complement it when policymakers aim to counter market failures that do not stem directly from demand (Borrás and Edquist 2013; Martin 2016). Unlike previous works that frame the analysis within the frame of a policy-mix (for instance, Guerzoni and Raiteri 2015; Caravella and Crespi 2021), I refrain from following the same strategy since RIL data does not provide the opportunity to properly account for such public interventions. This does not preclude following developments to tackle such an issue.

Although the outcomes in this work should be interpreted in terms of correlation rather than cause-effect, despite all the ways to counter potential forms of bias, the evidence of this work, from a policy point of view, may be of further use for the much wider debate on how to spur growth in stagnant economies. The positive correlation I identify, within the current context of a revitalized intervention through public demand (see the large echo on the PNRR national program), with all its limitations I mentioned, still provides hints to consolidate the existence of another way to stimulate innovation, which is particularly high on he agenda of policy makers, as it is considered a key factor in sustaining the GDP growth of countries. Especially in a country like Italy with a puzzling economic pattern that already suffers from a plentitude of elements that hinder doing business.

Acknowledgments

This work originates from a chapter of my PhD dissertation. I am very much grateful to Fabio Pieri and Fabio Landini as well as the editor and the anonymous reviewer for all the helpful comments and suggestions. Any remaining errors are mine alone.

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