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Effectiveness of public procurement in stimulating innovation in small and medium-sized enterprises (SMEs)

Abstract

A recent resurgence of demand-side innovation policy and, in particular, public procurement of innovation, has reignited the interest of policy makers as well as policy evaluators across the EU. While most evidence on its effectiveness are based on case studies, quantitative studies are scarce, especially for small and medium-sized enterprises (SMEs). We utilize the Innobarometer 2015 survey to estimate direct effects from public procurement of innovation and indirect effects from regular public procurement on innovation outputs in all firm size categories (micro, small, medium and large firms). Overall results suggest positive policy effects on product innovation in services and innovative sales. These results are broadly consistent across SME firm size categories and for both direct and indirect effects. In contrast, we found little evidence of policy effects among large firms. Based on empirical findings, our study offers policy implications in relation to facilitating innovation in SMEs using public procurement as a policy instrument.

Introduction

We distinguish between two types of procurement: public technology procurement; and regular or normal procurement (Edquist and Zabala-Iturriagagoitia, 2012; Uyarra and Flanagan, 2010). Public technology procurement occurs when a public sector organization purchases products or services that demand innovation by a supplier, such as R&D activities (Aschhoff and Sofka, 2009; Edquist and Hommen, 2000; Guerzoni and Raiteri, 2015; Uyarra and Flanagan, 2010). Scholars have recently introduced other terms to denote public technology procurement, such as “procurement for innovation” or “innovative procurement”, to extend the concept beyond R&D (Edler and Georghiou, 2007; Edquist et al., 2015; Edquist and Zabala-Iturriagagoitia, 2012; Uyarra and Flanagan, 2010). Accordingly, Edquist et al. (2015, pp. 6 -7) infer that: ‘Public Procurement for Innovation (PPI) occurs when a public organization places an order for the fulfilment of certain functions (that are not met at the moment of the order or call) within a reasonable period of time through a new or improved product.’

In contrast, regular or normal procurement refers to the purchase of ready-made products where contracts do not *require* any additional R&D or even broader innovative activities. Firms' innovation activities may be affected by public procurement even if that is not an explicit goal of policy makers. That is, although innovation may not be a direct result of procurement, it can occur indirectly or as a by-product (Guerzoni and Raiteri, 2015; Uyarra and Flanagan, 2010). Therefore, besides a direct intentional effect on innovation, public procurement can induce firms to innovate as a consequence of participation in a procurement tender, although its goal is not innovation itself. We termed these effects as "indirect". Accordingly, we investigate both direct effects of public procurement of innovation and indirect effects of regular public procurement on firms' innovation performance.[1]

Using public procurement as a policy instrument to promote innovation has recently appeared high on policy agendas across the EU (Edquist and Zabala-Iturriagagoitia, 2012; Uyarra and Flanagan, 2010). The proportion of public procurement in GDP is estimated to be approximately 12.8 per cent in the OECD countries (Loader, 2015; OECD, 2013) and 19.4 per cent across the 28 EU member states (Amann and Essig, 2015; EU COM, 2012). Until recently, the main policy instruments for promoting innovation were supply-side instruments, such as R&D subsidies, R&D tax credits, the protection of Intellectual Property Rights (IPRs) and support for collaborative innovation activities (Edler et al., 2012; Edquist et al., 2015). Nowadays, demand-side policy instruments, and its central area – the use of public procurement – are part of mainstream innovation policy in the EU (Edler et al., 2012; Edquist and Zabala-Iturriagagoitia, 2012; Edquist et al., 2015; Uyarra and Flanagan, 2010).The importance of public procurement of innovation is reflected in the Lead Market Initiative (European Commission, 2007), for which public procurement is considered to be a critical policy instrument (David and Brady, 2015; Uyarra and Flanagan, 2010).[2] This growing diffusion of public procurement of innovation calls for a quantitative evaluation of its

[1]This is similar to Rolfstam (2015) who distinguishes between public procurement *for* innovation and public procurement *of* innovation. He notes that the first concept does not incorporate incremental product innovation and process innovation, which is why he puts forwards the concept of public procurement of innovation. The latter encompasses any type of Schumpeterian innovation, which coincides with the broad definition of innovation defined in the Oslo Manual (OECD, 2005) encompassing technological, product and process, innovation, as well as non-technological, organizational and marketing, innovations.

[2]A lead market is a market with particular characteristics favourable to the introduction of a certain innovation (Edler et al., 2012).

effectiveness, especially since current evidence is based on case studies with little quantitative content (Aschhoff and Sofka, 2009; Guerzoni and Raiteri, 2015).

EU policy makers are particularly keen on increasing the engagement and participation of SMEs in public procurement as a means of supporting them (European Commission, 2011; Loader, 2013; Reijonen et al., 2016; Rolfstam, 2015). This trend is reflected in recent documents and reports issued by the European Commission (e.g. EC, 2011; EU Directives, 2014). Following this trend, most studies on SME and public sector tendering focus on barriers that firms face when competing for public contracts (Flynn et al., 2015). However, evidence from the existing literature offers only limited insights into SME participation in public sector contracting, reflecting both the dominance of supply-side policy measures (Flynn et al., 2015; Loader, 2013; Pickernell et al., 2011; Withey, 2011) and the absence of empirical evidence of the impact of such participation on either SME performance (Reijonen et al., 2016; Reis and Cabral, 2015) or on innovation performance (Pickernell et al., 2011). Our study focuses on the latter by evaluating the effectiveness of public procurement in promoting innovation in small and medium-sized enterprises (SMEs) across 28 EU Member States, plus Switzerland and the United States.

Previous empirical evidence (Guerzoni and Raiteri, 2015; Aschhoff and Sofka, 2009), although scarce, indicates that public procurement of innovation is effective in promoting firms' innovation inputs and market success. However, still absent is empirical evidence on the impact of public procurement (regular, and of innovation) on innovation outputs. Moreover, neither study focuses specifically on SMEs. Our aim is to fill these gaps by estimating the treatment effects on different measures of innovation output as well as of the market success of innovation in the context of SMEs and by comparing these estimates with those for large firms.

Our study contributes to the empirical literature on the innovation effects of public procurement in several ways. First, we focus on SMEs, as policy efforts across the EU are focused on reducing barriers to SME participation in public procurement tenders. To date, among the few empirical studies on innovation effects of public procurement, there is scarce empirical evidence on how public procurement promotes innovation in SMEs. Pickernell et al (2011) identify five emerging gaps in the literature on SMEs and public procurement. Relevant for the motivation of our study is the need to explore the impact of public procurement on innovative SMEs. We respond to this particular gap in the literature. Second, we report direct and indirect innovation effects depending on the type of public procurement

in which firms participate: the former stems from firms participating in the public procurement of innovation; while the latter measures the impact of regular procurement on firms' innovation. Third, we employ a range of innovation output indicators, both technological (product and process) and non-technological (organizational) innovations. There is no empirical evidence on these innovation indicators in relation either to the direct or to the indirect innovation effects of public procurement. We also utilize innovative sales as a measure of innovation output, which is the same measure used in Aschhoff and Sofka (2009). Fourth, our study is among the few to investigate heterogeneity within the SME population and corresponding modes of participation in public sector tendering. SMEs are not a homogenous group of firms but vary in their capabilities, objectives and obstacles across industry sectors and size groups (Flynn and Davis, 2015; Flynn et al., 2015; Karjalainen and Kemppainen, 2008; Loader, 2015; McKevitt and Davis, 2015; Morrissey and Pittaway, 2006).Flynn et al. (2015, p.445) note that 'not to recognise and make allowance for SME diversity in public sector tendering runs contrary to extant theory and empirical evidence'. However, scholars and policy makers focused on SME participation in public sector tendering overwhelmingly assume their homogeneity. Furthermore, by distinguishing between micro, small and medium-sized firms, and by including comparison with large firms, we are able to assess the effectiveness of "one-size-fits-all" public policies aimed at promoting "SME-friendly" public procurement processes (Flynn et al., 2015).

The study is organized as follows. The next section reviews the rationale for demand-side innovation policy, the literature on public procurement as a policy instrument for promoting innovation and, finally, discusses the benefits and limitations of public procurement in the context of SMEs and highlights the paucity of studies evaluating the effectiveness of public procurement as a means of promoting SME innovation. Next we explain our data and the matching estimator applied in estimating policy effects. Finally, we discuss our empirical findings and conclude with policy implications and noting limitations of the study.

Literature review

Rationale for demand-side innovation policy measures

Instruments in support of innovation are divided into two categories – technology push and demand (market) pull. The former instruments are associated with the supply side of innovation, whereas the latter emphasizes the importance of the demand side of

innovation. Supply-side measures stem from linear innovation models and have been a dominant category of public intervention in the domain of innovation since the market-failure rationale was advanced in theory and practice (Edler and Georghiou, 2007). The first generation of innovation models represent a linear, technology-push model that focuses on the supply side in innovation policies, ignoring the demand for innovation and the market conditions that influence the profitability of innovation (Nemet, 2009). The second generation of demand-pull innovation models shifted the focus to the demand side of the innovation process but, at the same time, ignored the role of firms' technological capabilities in the innovation process (Brem and Voigt, 2009; Nemet, 2009).

Demand-side public measures were designed after the formalization of the third-generation interactive or coupling innovation models. These models, and specifically the Kline-Rosenberg chain-linked model (Kline and Rosenberg, 1986) brought together the technology-push and the demand-pull arguments and emphasised several relevant features of the innovation process, not taken into consideration in linear innovation models; for instance, ascribing the crucial role in the innovation process to the demand for innovation (Edquist and Hommen, 1999).

Although there is no commonly accepted definition of demand-side innovation policies, OECD (2011) adopts the definition proposed by Elder and Georghiou (2007, p. 952):

> … demand-side innovation policies are defined as all public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirement for products and services or better articulating demand.

Examples of demand-side innovation policies include: tax credits and rebates for consumers of new technologies; technology-oriented public procurement; technology mandates; and innovation-specific regulations and standards (OECD, 2011).

Several qualitative and quantitative studies in the 1970s and 80s pointed out that public demand for innovation is an effective policy tool, perhaps even more efficient than R&D subsidies (Geroski, 1990). Although demand-side policy measures have been used in parallel with traditional supply-side measures in a few strategic sectors, such as construction, health care and transport (Edler and Georghiou, 2007), their wider diffusion was absent until recent years. Renewed interest from policy-makers at both national and EU levels during the last decade is a consequence of the realization that supply-side measures alone are not

sufficient to promote innovation and enhance competitiveness and that, instead, supply-side and demand-side policy measures are complementary (Edler and Georghiou, 2007; OECD, 2011; Pickernell et al., 2011; Uyarra et al., 2014).[3]Consistent with this trend, Edler and Georghiou (2007) recognized the importance of public procurement in innovation policy, which is echoed in OECD (2011, p.11): '… public procurement is at the heart of demand-side innovation policy initiatives' (Davis and Brady, 2015). Consequently, the United Kingdom, Germany, the Netherlands, Finland and Spain have put in place legislation and programmes for integrating innovation in public procurement.

The evolutionary approach of system failures has led to the articulation of the innovation systems perspective. Within this perspective, public policy is oriented towards optimising the interaction between different elements of the system, including industry, basic and applied research, and demand (Edler and Georghiou, 2007). However, even though the innovation systems approach is being adopted by national and EU policy makers, demand has been outside of the policy focus until recently (Edler and Georghiou, 2007; Uyarra and Flanagan, 2010).

Edler and Georghiou (2007) identify asymmetric information as one of the main sources of market failures and poor interaction between potential suppliers and users as the main source of systemic failures, both of which can be overcome by public procurement (Georghiou et al., 2014). Regarding the former, lack of information is characteristic at both ends of the value chain. Accordingly, both private and public customers might not be aware of innovative goods and services that are available in the marketplace or that could be supplied if sufficient demand were to occur. On the other hand, innovating firms might not have timely information about future trends in the demand, which would enable them to meet that demand with new products and services. When these information and interaction barriers are overcome, public procurers can enhance demand for innovation that will result in increased innovation activities at the firm level (Uyarra et al., 2014). In the context of SMEs, market failures can, in particular, occur with respect to the difficulties in accessing information and advice relevant for innovation (OECD, 2014). In addition, the use of public procurement by the public sector can mitigate market failures by increasing demand for

[3]OECD (2014) identifies three potential reasons as to why the demand-side measures in innovation policy have attracted renewed interest from policy makers. First, demand-side innovation policy might stimulate innovation to meet societal needs. Second, demand-side measures might be more cost effective than the traditional supply-side measures. Finally, the renewed interest might be motivated by the rather disappointing effects of the supply-side measures (or they were insufficient alone to foster innovation, Pickernell et al., 2011).

certain products – especially those with insufficient private demand –and thus provide incentive for firms to invest in R&D (Uyarra, 2012).

Poor interaction between suppliers and customers occurs, for instance, when dispersed demand hampers suppliers in identifying customers' needs and from timely offering of new products to meet these needs (Edler and Georghiou, 2007). Consequently, concerning the role of public procurement in addressing systemic failures, any improved interaction between suppliers and users via public procurement mitigates systemic failures (Uyarra et al., 2014). In addition, by purchasing innovative goods and service, government as the lead user can signal the usefulness of new products and services to the market and private users and thus facilitate the diffusion of innovation (OECD, 2011; Uyarra and Flanagan, 2010). Another way that governments, using public procurement, can facilitate innovation is by helping firms to recover the sunk costs of large and sometime risky investments (OECD, 2011). From the perspective of SMEs, systemic failure, in particular, institutional failure can occur via less favourable conditions in relation to public procurement (see Section "SMEs and public procurement" below).

Public procurement and innovation

Public technology procurement is a demand-side policy instrument whereby a public agency determines the output of a tender, while the procurement supplier determines the optimal way to achieve a desired output (Aschhoff and Sofka, 2009). In other words, the procurer should stipulate the functions of a future product, but not its technical specifications (i.e. the product itself). This has the advantage that the supplier can pursue its creativity and innovation activities in fulfilling the requirements of a tender (Edquist el al., 2015). Another advantage that firms derive from public procurement is reduction in market risk, which is otherwise inherent to innovation activities. That is, by purchasing new products or services, the government eliminates the market risk that firms would otherwise face in commercializing their innovations (Aschhoff and Sofka, 2009).

By influencing the demand for innovation, public procurement can affect both product and process innovations in two ways. First, the "incentive effect" occurs when firms expect higher profitability in the future, as a result of innovation. That is, if firms reduce costs through improvements in their production techniques (i.e. introduce process innovation) or/and enhance the quality of an existing product (thus, introduce incremental product innovation) then these changes positively affect the future stream of profits. This incentive

effect is positively associated with market size, which is a proxy for expected demand (Schmookler, 1962; Fontana and Guerzoni, 2008). Second, the "uncertainty effect" occurs when firms engage in radical innovations. Namely, the demand for radical innovation can positively affect its introduction and diffusion by reducing uncertainty through the provision of relevant information and knowledge about market needs and users' requirements (Myers and Marquis, 1969; Fontana and Guerzoni, 2008).

In their review of earlier examples of public procurement, Uyarra and Flanagan (2010) conclude that public procurement will less likely result in radical innovation and more likely in incremental innovation and even non-technological innovations (see e.g. Lember et al., 2011; Yaslan, 2009).[4] Our data does not allow us to distinguish between radical and incremental innovation. However, we do have data on firms' activities in relation to technological, product and process innovations, as well as non-technological, organisational, innovations. Thus, we attempt to assess how regular public procurement together with public procurement of innovation influence both technological and non-technological innovations. We term the impact of regular procurement on innovation as an *indirect* effect, whereas the impact of public procurement of innovation is regarded as a *direct* effect. This distinction is consistent with Cave and Frinking (2003), who recognize direct demand-pull effects, arising from government procuring innovative goods and services, and indirect demand-pull effects, when regular public procurement induces innovation as a by-product (Uyarra and Flanagan, 2010). There are three types of indirect effects (Cabral et al., 2006). First, public procurement can enlarge the market for new goods up to a critical level that will provide incentives for firms to invest in innovation. Second, public procurement can facilitate the creation of new standards in relation to new technologies, which is particularly relevant for information and communication technologies (ICTs) (Uyarra and Flanagan, 2010). This, in turn, similar to the first type of indirect effects, might create sufficient demand for a product, thus enabling procuring firms to achieve economies of scale in production and diffusion. Third, public procurement can change the market structure such that procuring firms gain more market power than their competitors.

Lember et al. (2014) identify two approaches to relating public procurement of innovation with firms' innovation activities. The first approach posits that public procurement

[4]In relation to the level of innovativeness, Edquist and Zabala-Iturriagagoitiaa (2012) distinguish between three types of PPI. First is pre-commercial procurement, which does not entail the delivery of a final product, but rather of research results. Second, adaptive PPI involves the delivery of an incremental innovation (Davis and Brady, 2015). Third, developmental PPI results in radical innovation (new to the world).

will enhance product innovation, both radical (new to the world), as well as incremental (new to the country or a region).[5] The second approach takes a wider stance on the impact of public procurement by taking into account not only an expected positive effect on product innovation, but also assuming a beneficial impact on firms' organisational and technological capabilities. Therefore, these two approaches are in line with Rolfstam's (2015) distinction between public procurement *for* innovation (the first approach) and public procurement *of* innovation (the second approach). As noted above, our study reflects the second approach, as we explore the impact of public procurement on product innovation as well as on process and organisational innovations (and the market success of innovation), while being unable to distinguish between radical and incremental innovation.

The concept of innovation-friendly public procurement can also be related to the indirect effects of public procurement. Following Edquist et al. (2015, p.7), 'innovation-friendly public procurement is regular procurement which is carried out in such a way that new and innovative solutions are not excluded or treated unfairly'. This definition implies that innovation-friendly public procurement will not necessarily result in innovation, but may facilitate it, for instance, by including innovation-related criteria in the tender specifications and in the assessment of tender documents (OECD, 2011; Edquist et al., 2015). Arguably, innovation-friendly public procurement should be formulated in functional terms, rather than as descriptions of products. In this way, public agencies will avoid conducting regular public procurement in a routine manner, repeatedly requiring the same products (Edquist et al., 2015). Instead, by formulating the tender in functional terms, but not describing the product to be delivered, public agencies leave space for firms to be creative and innovative in offering new solutions. Innovation-friendly regular public procurement may have a significantly larger potential as an innovation policy instrument than both Public Procurement for Innovation (PPI) and Pre-Commercial Procurement (PCP) (Edquist, 2014; Edquist and Zabala-Iturriagagoitiaa, 2012). The importance of innovation-friendly public procurement is reflected in the recently adopted new directives on public procurement set by the European Parliament in January 2014. Besides the price, additionally important criteria for selecting a winning tender are: quality; sustainability; social conditions; and innovation (Edquist et al., 2015).

[5]Following Edquist and Zabala-Iturriagagoitiaa (2012), adaptive public procurement of innovation leads to incremental innovation, while developmental public procurement of innovation encompasses the introduction of radical innovation.

SMEs and public procurement

SMEs play a critical role in an economy because they contribute to economic growth through innovation, job creation and competition (Albano et al., 2015; Loader, 2015). However, particularly in the aftermath of the global financial crisis, SMEs often identify limited demand for their products as their leading economic problem (Flynn and Davis, 2015; Loader, 2015). Accordingly, the public sector, through public procurement, could compensate for reduced private demand and thus help to sustain and develop SMEs by helping them to innovate. Conversely, SMEs can provide benefits for public procurement, most prominently because of their entrepreneurial orientation, specialist knowledge, innovativeness, adaptability and rapid response to changes in demand (Flynn et al., 2015; Karjalainen and Kemppainen, 2008; Loader, 2013; Woldesenbet et al., 2012). However, SMEs have traditionally a low rate of participation in public sector contracting relative to their weighting in the economy (Flynn and Davis, 2015; Harland et al., 2013; Loader, 2013, 2015).[6]

Evidence on the effectiveness of public procurement of innovation is scarce and mostly based on case studies, such as in OECD (2011). In evaluating public procurement, OECD (2014) notes that firms might self-select themselves in a public procurement tender, i.e. those firms that are more likely to innovate have higher propensity to apply for a tender. In addition, public agency might adopt the "picking-the-winner" strategy, whereby firms might be selected on the basis of their innovation capabilities (such as, a proven track record). Therefore, similar to the traditional supply-side measures, quantitative evaluation has to take into account the potential endogeneity of innovation procurement.

[6]Several studies report a range of barriers to SME participation which can be categorized into two groups: barriers associated with the public sector; and those related to SMEs' limited resources and capabilities (Karjalainen and Kemppainen, 2008; Loader, 2013, 2015). The former encompasses the contract size (Albano et al., 2015; Flynn et al., 2015; Karjalainen and Kemppainen, 2008; Loader, 2013); overly prescriptive requirements and other aspects of the bidding process, such as extensive documentation, the time and cost needed for the preparation of offers (Albano et al., 2015; Edquist and Zabala-Iturriagagoitiaa, 2012; Flynn et al., 2015; Karjalainen and Kemppainen, 2008; Uyarra et al., 2014), and a lack of feedback from public procurement staff (Flynn et al., 2015; Loader, 2015; Uyarra et al., 2014). The second category of barriers related to firms' internal resources and capabilities includes a lack of electronic resources, marketing skills and legal expertise (Karjalainen and Kemppainen, 2008; Loader, 2015; McKevitt and David, 2013; Reijonen et al., 2016). Previous studies report that micro firms are particularly disadvantaged in the process of public procurement. Flynn and David (2015) found that Irish micro firms have benefited less from the introduction of SME-friendly public procurement practice than small and medium-sized firms. Albano et al. (2015) report that Italian micro and small firms are less likely to be awarded the larger contract values in e-procurement than medium-sized firms. Flynn et al. (2015) report differences between Irish micro, small and medium-sized firms with respect to the tendering resources, the number of employees involved in the tendering process, frequency of tendering and its success. The results indicate that micro firms are "most resource-disadvantaged, least active in tendering and having the lowest rates of success" (Flynn et al., 2015, p. 456).

Up to date, only two studies by Aschhoff and Sofka (2009) and Guerzoni and Raiteri (2015) report empirical findings on the effectiveness of public procurement in promoting innovation and both studies utilize matching estimators, as a quantitative technique designed to address the potential endogeneity of procurement considered as a policy treatment. Aschhoff and Sofka (2009) find that public procurement increases German firms' market success, especially for smaller firms located in regions under economic stress. In turn, this may suggest that public procurement is particularly effective for firms with limited internal resources (Pickernell et al., 2011). Guerzoni and Raiteri (2015) investigate how interaction between public procurement of innovation, R&D tax credits and R&D subsidies affect innovation expenditure. The data utilized in their study is the Innobarometer data on "Strategic Trends in Innovation 2006-2008", which was conducted in 2007 in 27 EU member states, Norway and Switzerland. The results from propensity score matching suggest that public procurement of innovation has a positive impact on innovation inputs when this policy tool is considered separately, as well as when analysed in combination with R&D subsidies and R&D tax credits.

Methodology

Data

We utilize the Innobarometer survey 2015 - "The innovation trends at EU enterprises" – which includes firms from 28 EU Member States, Switzerland and the United States (European Commission, 2015a) and the period January 2012 to February 2015. The survey was requested by the European Commission, DG for Internal Market, Industry, Entrepreneurship and SMEs (for details on sampling see European Commission, 2015a). In total, 14,118 firms were interviewed, from which 13,134 firms are SMEs (93 per cent of the whole sample). Therefore, the survey coverage is highly skewed towards SMEs, while enabling comparison with large firms.

In addition, our analysis includes only firms that are innovators. Following Aschhoff and Sofka (2009), in order to mitigate a potential selection bias arising from a non-random selection of firms in the sample, we excluded non-innovating firms (defined in a broad sense, as firms that introduce neither technological nor non-technological innovations), so the final sample amounted to 9,592 innovative SMEs (4,171 micro firms, 3,328 small firms and 2,093

medium-sized firms) together with 897 large firms.[7]The definition of innovation adopted in the survey is as follows. "Innovation occurs when a company introduces a new or significantly improved good, service, process, marketing strategy or organizational method. The innovation can be developed by the company itself or has been originally developed by other companies or organizations." This broad definition of innovation is in accordance with the *Oslo Manual* (OECD, 2005), thus encompassing both technological (product and process) innovations and non-technological (marketing and organizational) innovations.[8]

For each firm size category, Table 1 shows the number and share of firms that won at least one tender as well as those that included innovation as part of a public procurement contract. Out of the total number of innovative firms, less than a third (27.8 per cent) of micro firms have won at least one tender, while the shares of medium and large firms are the highest (44.2 and 44.4 per cent respectively). A similar pattern is exhibited for innovative firms that won at least one tender and, in addition, included innovation in public procurement contracts; the share of micro firms is the smallest (34.3 per cent), whereas the share of large firms is the largest (52.8 per cent). Therefore, our sample reflects the general conclusion from the literature with respect to the lower participation of smaller firms in public procurement tendering.

Table 1. Number and percentage of firms per firm size categories that have won at least one tender and that included innovation in public procurement.

Firm size categories	Number of firms that won at least one tender	Percentage of innovating firms that won at least one tender	Number of firms that included innovation in public procurement	Percentage of firms that won at least one tender and included innovation in public procurement contract
Micro firms	1,159	27.79	398	34.34
Small firms	1,397	41.98	529	37.87
Medium-sized firms	924	44.15	378	40.91
Large firms	398	44.37	210	52.76

[7] Following the new European Commission (2008) guidelines, micro-sized firms are defined as those with fewer than 10 employees, small firms with more than 10 and fewer than 50 employees and medium-sized firms with more than 50 and fewer than 250 employees (as adopted in e.g. Flynn et al., 2015; [Authors, 2016]).

[8] We do not investigate the treatment effects of public procurement on marketing innovation, given the nature of this policy instrument, i.e. its purpose to substitute private demand. Thus, we do not expect public procurement to induce marketing innovations.

Matching estimators

Matching estimators are the most commonly applied evaluation method in innovation studies (Cerulli 2010). They rely on two identifying assumptions. The first assumption is the conditional independence assumption (CIA) or selection on observables, which posits that the outcome in case of no treatment (Y_0) is independent of treatment assignment, conditional on covariates X (Imbens 2004; Imbens and Wooldridge 2009). That is,

$$Y_0 \coprod D|X \quad (1)$$

where X represents a vector of covariates and D is the treatment assignment.

The second assumption is associated with the overlap or common support condition, where the estimated propensity scores take values between zero and one (see Equation 2) (Heckman and Vytilacil, 2007; Smith and Todd, 2005). The overlap condition thus implies that both treated and non-treated firms have a positive probability (P) of receiving a treatment (D=1) or not receiving a treatment (D=0).

$$0 < P(D = 1|X) < 1 \quad (2)$$

The treatment of interest is the Average Treatment Effect on the Treated (ATT), which indicates the difference in outcomes of the treated firms with and without treatment and can be written as:

$$ATT = E[Y_1|D = 1] - E[Y_0|D = 1] \quad (3)$$

The first term on the right-hand side of Eq. (3), $E[Y_1|D = 1]$, is the expected outcome for subsidised firms conditional on their participation, while the second term $E[Y_0|D = 1]$ is the expected outcome had treated firms not participated in the public support programme. This second term refers to a counterfactual outcome that is not observed but estimated.

Concerning the choice of covariates X, the literature suggests that all observed variables that simultaneously affect treatment assignment and the outcome should be included (Austin, 2011; Caliendo and Kopeinig, 2008; Ho et al., 2007; Steiner and Cook, 2010). After the selection of matching variables, the next step in the matching protocol is the

estimation of the propensity score model either using probit or logit models as they usually yield similar results (Caliendo and Kopeinig, 2008).

Next, we select the matching algorithm. We utilize the Inverse Probability Weighing Regression Adjustment (IPWRA) estimator. The main advantage of the IPWRA estimator is its double robust property. If either the propensity score model (the outcome model) or the treatment model is correctly specified, then this estimator will yield treatment effects with a lower bias than will other estimators that are not characterized by the double robustness property. Busso et al. (2014) conducted a Monte Carlo simulation of the finite sample of matching and reweighting estimators – which include the IPWRA – in the estimation of ATTs. Their findings support our use of the IPWRA: first, we use normalised reweighting, which exhibits overt bias of the same magnitude as pair matching but much smaller variance; second, their findings suggest that normalised reweighting outperforms matching estimators when overlap is good, which is the case in our study (see Figures 1 and 2).

The estimator consists of three steps: first, the propensity score model - the treatment model- is estimated. Second, the inverse of the estimated propensity scores (probabilities of receiving a certain level of treatment) are used as weights in the regression analysis. Third, the ATT is computed as the difference in the weighted averages of the predicted outcomes (for technical details see Wooldridge 2007, 2010). This three-step approach provides consistent estimates given the underlying assumption of the independence of the treatment from the predicted outcomes once covariates are modelled in steps 1 and 2. We report valid standard errors (of the Huber/White/sandwich variety) which take into account that the estimates are computed in a three-step approach (Emsley et al. 2008).

Model specification

The treatment variables are a binary indicator for firms that won at least one public procurement tender (for estimating indirect effects), and a binary indicator for firms that innovate because they won a tender (for estimating direct effects) (see Table A1. for variable descriptions). Consequently, as previously noted, we investigate both direct effects of public procurement of innovation on firms' innovation performance and indirect effects of public procurement. We are able to investigate direct treatment effects, as firms in the sample were asked "Has your company included any of its innovations as part of any public procurement contract that you have won?".Similar treatment variablesare used in Aschhoff and Sofka (2009) and Guerzoni and Raiteri (2015). An indirect effect is investigated by estimating

treatment effects of public procurement on different measures of innovation output, without taking into account whether or not firms included their innovation in a public procurement contract. That is, the treatment is equal to one if the firm had won at least one tender and zero otherwise. This indirect effect enables us to test the proposition that innovation is often a by-product of regular public procurement (Guerzoni and Raiteri, 2015; Uyarra and Flanagan, 2010). So far, this argument has not been empirically investigated and thus we provide the first empirical results on indirect effects of public procurement on innovation.

The outcome variables are binary indicators for the introduction of technological – product and process –innovations (product innovation is divided into goods and services) and non-technological, organizational, innovations. Following Aschoff and Sofka (2009), innovative sales as a measure of the commercial success of innovation is also used as the outcome variable (see Table A1 for variable description).

To account for firm and market characteristics, we include the following covariates in the outcome model. Firm size is a categorical variable equal to 1 for micro firms (between 1 and 9 employees); 2 for small firms (between 10 and 49 employees); and 3 for medium firms (between 50 and 249 employees). Firms' exporting activities are measured as a percentage of firms' total revenues that came from sales in foreign markets (Aschoff and Sofka, 2009; Guerzoni and Raiteri, 2015). We also specify a binary indicator for firms that belong to an enterprise group (Czarnitzki and Hottenrott, 2011; Czarnitzki and Lopes-Bento, 2014). The variable *Young* is equal to 1 if a firm was established after 2009, and zero otherwise. This variable is included to control for business experience (Reis and Cabral, 2015), as it can be assumed that older firms have more experience in bidding for public tenders than their younger counterparts. However, Reis and Cabral (2015) found that younger firms are more likely to win a tender. They interpret this result in relation to the selection process, whereby if value for money is the main criterion, then experience plays an insignificant role in the process. To account for firms' financial performance, we included two dummy variables: *Rising turnover* (DV=1 if a firm reported a rising turnover since 2012, zero otherwise) and *Falling turnover* (DV=1 if a firm reported a falling turnover since 2012, zero otherwise) (the base category is *Turnover remained the same*).

As a measure of firms' absorptive capacity (Cohen and Levinthal, 1990), we utilize the following question: "Approximately what percentage of your company's revenue in 2014 was invested in innovation activities?" to create a categorical variable Innovation expenditure equal to zero if a response was "0%"; =1 if a response was "less than 1%"; =2 if a response

was “between 1 and 5%”; = 3 if a response was “between 6 and 10%”; =4 if a response was “between 11 and 15%”; and =5 if a response was“16% and more”. Similarly, we created seven categorical variables to measure firms’ R&D and non-R&D activities that affect innovation capacity (variables *Training, Software, Branding, R&D, Design, Process improvement*, and *Acquisition*, see Table A1 for variable description). Firms in low- and medium-technology sectors often innovate without R&D, focusing on adaption and learning by doing through design and process improvements (Huang et al., 2010). In addition, firms can innovate without R&D by combining existing knowledge in new ways, utilizing industrial design and engineering activities (Grimpe and Sofka, 2009; Huang et al., 2010).

Finally, country effects are captured by four dummies for “Innovation leaders” country group, “Innovation followers”, “Moderate innovators”, and “Modest innovators” (“Moderate innovators” are the base category) (according to the European Innovation Scoreboard, European Commission 2015b) (see Table A1 for the list of countries in each group).[9] To control for industry effects, we utilized the already-created variable in the dataset dividing industries into four categories: manufacturing (NACE category C); retail (NACE categories G); services (NACE categories H, I, J, K, L, M, N, and R); and industry (NACE categories D, E, and F). The base category is manufacturing.

Results and discussion

Before proceeding with the interpretation of empirical results, we check for the overlap condition. The plots depicted in Figures 1 and 2 show that the overlap or the common support condition is satisfied in all reported models, given that the probabilities of participation (treatment =1) or not participating in public procurement (treatment=0) are between zero and one (and not too close to the boundary values) (Cattaneo et al., 2013). In addition, we utilize a formal test developed by Imai and Ratkovic (2014) for checking whether each treatment model balances the covariates. The tests for all treatment models indicate that the covariates are balanced (results not reported, but available on request).

The estimated treatment effects are reported in Table 2. In micro firms, the direct effects are positive and highly statistically significant (at the 1% level) for product innovation in services and for innovative sales. Namely, including innovation in a public tender

[9]The European Innovation Scoreboard publishes the average innovation performance based on a composite indicator, encompassing 25 individual indicators. Innovation performance of each Member State is then compared to the average innovation performance of 28 EU Member States.

increases the probability of product innovation in services by 10.9 percentage points, while innovative sales is higher by 9.3 percentage points in firms that included innovation in public tendering relative to those micro firms that did not include any innovation.[10] Similar results are reported for indirect effects. Winning at least one tender relative to non-participation in public tendering increases the probability of product innovation in services by 4.6 percentage points and innovative sales by 8.2 percentage points.

In small firms, direct effects are statistically significant for product innovation in services, process innovation, organizational innovation (at the 10% level) and for innovative sales. Quantitatively, including innovation in public tendering increases the likelihood of product innovation in services by 5.7 percentage points, of process innovation by 8.3 percentage points, of organizational innovation by 4.8 percentage points, while innovative sales is higher by 8.7 percentage points relative to small firms that did not include innovation in public procurement contracts. Concerning indirect effects, we found no statistically significant effect for any innovation output indicator.

In medium-sized firms, direct policy effects are significant for product innovation in services and for innovative sales. Including innovation in public tendering increases the probability of product innovation in services by 10.6 percentage points, while innovative sales is higher by 13.3 percentage points relative to firms that did not include innovation as a part of public procurement. With respect to indirect effect, the estimated ATT effect is significant for product innovation in services; medium-sized firms that have won at least one tender have the higher probability of introducing product innovation in services by 6.7 percentage points relative to medium-sized firms that have not won any public contracts.

Finally, in large firms, we found significant direct effects for organizational innovation. That is, the probability of this type of innovation increases by 10.6 percentage points in large firms that included innovation as a part of tendering relative to their counterpart that did not include innovation. Regarding indirect effects in large firms, a significant ATT is found for product innovation in services. Thus, large firms that won at least one tender are 9.2 percentage points more likely to engage in product innovation in services than large firms that have not participated in public tendering.

[10]To quantitatively interpret the estimated treatment effects for *Innovative sales* (regarded as a continuous variable in our estimations), we estimated the means of the predicted outcomes for each treatment level (the comparison group) and calculated the percentage change between the estimate ATTs and the means of the predicted outcomes for the comparison group (Row "Innovative sales in percentages" in Table 2).

Our findings on the overall lack of influence of public procurement on product innovation in goods but a significant effect on public innovation in services is consistent with Uyarra et al. (2014), who found that public procurement in the UK is less likely to increase product innovation but more likely to positively affect service innovation. Reijonen et al. (2016) note that procurement of services is likely to involve innovative approaches because services are more complex than products, customer needs are specific and determining the quality of services are difficult. In addition, Loader (2015) and Reijonen et al. (2016) suggest that local SMEs can be in particularly good position to supply local government with services that have a local dimension.

Unlike Flynn et al. (2015), who report that Irish micro-firms are disadvantaged compared to small and medium-sized firms with respect to participation in public tendering, we found similar treatment effects on innovation performance across all three size groups. Therefore, although micro firms have less human and financial resources to compete in the public sector marketplace, those micro firms that win tenders benefit from them to a similar magnitude regarding their innovation performance as similar to their larger counterparts.

Conclusions and policy implications

Our study provides the first quantitative evidence on the impact of public procurement on SME innovation. As EU innovation policy makers only recently began focusing on demand-side policy instruments, most notably public procurement, empirical evidence on the effectiveness of this policy measure are scarce. We investigate the direct and indirect impact of public procurement on the introduction of technological and non-technological innovations as well as on the market success of innovation.

We can draw two conclusions from our empirical results. First, public procurement increases the probability of product innovation in services and the commercial success of innovation. Second, the firm size analysis reveals that all SME groups – micro, small and medium firms – experience a positive influence of participation in public tendering on their innovation outputs. However, although direct and indirect effects vary depending on how innovation output is measured, two findings are persistent for all group categories; namely, the positive direct effect on product innovation in services and on innovative sales. These results are in contrast to the results obtained for large firms. That is, we found that only organizational innovation increased as a result of public procurement of innovation, unlike product innovation in services and innovative sales, that were positively affected in SMEs.

Regarding indirect effects, large firms that participate in public tendering increase their product innovation in services, but not other innovation output indicators nor innovative sales.

Our results show that the direct and indirect effects of public procurement are broadly consistent across micro, small and medium-sized firms, but not for SMEs relative to large firms. Therefore, although these categories of firms may be disadvantaged in accessing and participating in public procurement tendering, those SMEs that participate benefit with respect to their innovation activities to a similar magnitude. From the perspective of revenue generation, our findings are particularly relevant, because they show that all three categories of SMEs experience an increase in innovative sales due to public procurement. The magnitude of the estimated treatment effects from our discussion in the preceding section indicates that these effects are both plausible and economically substantial (i.e. neither too large to be implausible nor too small to be of policy interest).

Our results offer some policy implications. The first implication is that EU and national policy makers should continue efforts in reducing barriers to SME participation in public tendering, because their participation positively affects innovation activities in respect of both technological aspects and the commercial success of innovation. Secondly, all firm size categories – micro, small and medium-sized firms –experience a similarly positive direct effect of public procurement, while indirect effects differ such that micro and medium firms increase their innovation, while our evidence is less strong that small firms increase innovation as a by-product of public procurement. Thirdly, our findings indicate a particularly strong return from involving SMEs in public procurement, while large firms do not experience similar effects as SMEs, in particular with regards to innovative sales, i.e. the market success of innovation. Therefore, recent efforts of national and EU policy makers to increase SME participation in public tendering are justified in our study.

It can be assumed that evaluation of demand-side innovation policy will develop in parallel to the prominence of demand-side policy instruments, following the pattern exhibited when policy instruments in support of collaborative R&D were introduced and developed together with their evaluation (Edler et al., 2012). Thus, a co-evolution of the demand-side innovation policy-making and evaluation of such policy is required to improve our understanding of this type of policy measure and its effectiveness in stimulating innovation (Edler et al., 2015).

Our study's limitations can also serve as suggestions for further research on assessing the effectiveness of public procurement in promoting SME innovation. First, the data on the amount of a public procurement contract are unavailable, which prevents us from investigating how the scale of public procurement affects firm innovation performance. Secondly, public procurement is likely to affect firms' innovation output in the medium and longer run (Edler et al., 2012). However, this impact cannot be explored in a cross-sectional setting. Therefore, availability of panel data would allow evaluators to assess the effectiveness of innovative public procurement over time (Flynn et al., 2015). Finally, a more fined-grained analysis at the individual country level would enable the comparison of findings between countries. In addition, the analysis could be conducted at the country group level (Leaders, Followers, Moderate and Modest innovators).

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Table 2. The estimated Average Treatment Effects on the Treated (ATTs) using the IPWRA estimator.

Outcome variables	Micro firms		Small firms		Medium firms		Large firms	
	Direct effects	Indirect effects	Direct effects	Indirect effects	Direct effects	Indirect effects	Direct effects	Indirect effects
Product innovation in goods	0.047 (0.029)	0.007 (0.020)	-0.008 (0.029)	-0.022 (0.021)	0.003 (0.033)	0.020 (0.026)	0.050 (0.051)	0.003 (0.043)
Product innovation in services	0.109*** (0.026)	0.046*** (0.020)	0.057** (0.026)	0.031 (0.021)	0.106*** (0.033)	0.067*** (0.027)	0.081 (0.051)	0.092** (0.042)
Process innovation	0.024 (0.032)	-0.007 (0.020)	0.083*** (0.028)	0.020 (0.022)	0.041 (0.033)	-0.028 (0.027)	0.001 (0.046)	-0.015 (0.040)
Organizational innovation	0.009 (0.029)	-0.000 (0.020)	0.048* (0.027)	0.021 (0.021)	0.033 (0.034)	-0.010 (0.027)	0.106** (0.052)	0.066 (0.045)
Innovative sales	0.224*** (0.089)	0.184*** (0.062)	0.203*** (0.076)	0.085 (0.059)	0.292*** (0.091)	0.063 (0.071)	0.118 (0.125)	0.034 (0.107)
Innovative sales (in percentages)	0.093** (0.038)	0.082*** (0.028)	0.087** (0.034)	0.039 (0.027)	0.133*** (0.044)	0.031 (0.035)	0.057 (0.062)	0.017 (0.053)

Notes: Robust standard errors in parentheses; ***p<0.01; **p<0.05; * p<0.10.

Table A1. Variable description.

Variables	Variable description
Treatment variables	
Public procurement	DV =1 if a firm responded "yes" to the question: "Since January 2012 has your company won at least one public procurement contract?"; zero otherwise
Public procurement of innovation	DV =1 if a firm responded "yes" to the question: "Has your company included any of its innovations as part of any public procurement contract that you have won?"; zero otherwise
Outcome variables	
Product innovation in goods	DV =1 if a firm introduced new or significantly improved goods since January 2012; zero otherwise
Product innovation in services	DV =1 if a firm introduced new or significantly improved services since January 2012; zero otherwise
Process innovation	DV =1 if a firm introduced new or significantly improved processes (e.g.production processes or distribution methods)since January 2012; zero otherwise
Organizational innovation	DV =1 if a firm introduced new or significantly improved organizational methods (e.g. knowledge management or the work environment)since January 2012; zero otherwise
Innovative sales	=0 if a firm responded "0%" to the question: "Approximately what percentage of your company's revenue in 2014 was due to innovative goods or services that have been introduced since January 2012?"; = 1 if a firm responded "Between 1 and 5%"; =2 if a firm responded "Between 6 and 10%"; =3 if a firm responded "Between 11 and 25%"; =4 if a firm responded "Between 26 and 50%"; = 5 if a firm responded "51% or more"
Independent variables	
Firm size	= 1 if a firm has less than 10 employees; = 2 if a firm has more than 9 and less than 50 employees; = 3 if a firm has more than 50 and less than 250 employees
Young	DV=1 if a firm was founded after January 2009; zero otherwise
Group	DV = 1 if a firm belongs to an enterprise group; zero otherwise
Export	Percentage of firms' total revenues from selling goods and services abroad
Rising turnover	DV= 1 if a firm reported a rising turnover since January 2012; zero otherwise
Falling turnover	DV= 1 if a firm reported a falling turnover since January 2012; zero otherwise
Turnover remained the same (base category)	DV= 1 if a firm reported an approximately the same turnover since January 2012; zero otherwise
Innovation expenditure	=0 if a firm responded "0%" to the question: "Approximately what percentage of your company's revenue in 2014 was invested in innovation activities?"; =1 if a firm responded "less than 1%", =2 if a

	firm responded “between 1% and 5%”; = 3 if a firm responded “between 6% and 10%”; = 4 if a firm responded “between 11% and 15%”; = 5 if a firm responded “16% and more”
Training	=0 if a firm responded “0%” to the question: “Since January 2012, what percentage of its total revenue has your company invested in training?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
Software	=0 if a firm responded “0” to the question: “Since January 2012, what percentage of its total revenue has your company invested in software development?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
Branding	=0 if a firm responded “0%” to the question: “Since January 2012, what percentage of its total revenue has your company invested in company reputation and branding, including web design?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
R&D	=0 if a firm responded “0%” to the question: “Since January 2012, what percentage of its total revenue has your company invested in research and development (R&D)?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
Design	=0 if a firm responded “0%” to the question: “Since January 2012, what percentage of its total revenue has your company invested in design of products and services?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
Process improvement	=0 if a firm responded “0%” to the question: “Since January 2012, what percentage of its total revenue has your company invested in organization or businessprocess improvements?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
Acquisition	=0 if a firm responded “0%” to the question: “Since January 2012, what percentage of its total revenue has your company invested in acquisition of machines, equipment, software orlicenses?”; = 1 if a firm responded “less than 1%”; =2 if a firm responded “between 1% and 5%”; = 3 if a firm responded “more than 5%”
Leaders	DV=1 if a firm is located in Denmark, Finland, Germany, Sweden, Switzerland and USA; zero otherwise
Followers	DV=1 if a firm is located in Austria, Belgium, France, Ireland, Luxembourg, Netherlands, Slovenia and United Kingdom; zero otherwise
Moderate innovators (base	DV=1 if a firm is located in Croatia, Cyprus, Czech Republic, Estonia,

category)	Greece, Hungary, Italy, Lithuania, Malta, Poland, Portugal, Slovakia and Spain; zero otherwise
Modest innovators	DV=1 if a firm is located in Bulgaria, Latvia and Romania; zero otherwise
Manufacturing (base category)	DV=1 if a firm operates in the NACE category C; zero otherwise
Retail	DV=1 if a firm operates in the NACE category G; zero otherwise
Services	DV=1 if a firm operates in the NACE categories H, I, J, K, L, M, N, and R; zero otherwise
Industry	DV=1 if a firm operates in the NACE categories D, E, and F; zero otherwise

Figure 1. Checking the overlap condition in the models estimating direct effects.

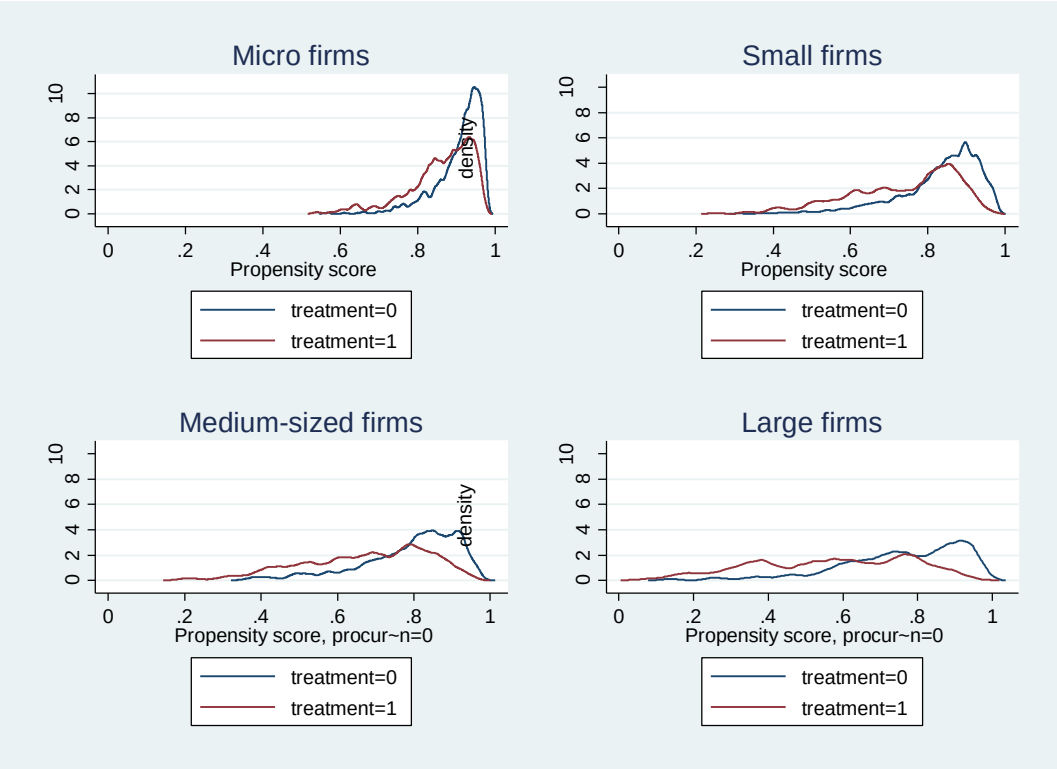

Figure 2. Checking the overlap condition in the models estimating indirect effects.