Public procurement for innovation: Are small firms really disadvantaged?

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Abstract

This paper focuses on public procurement for innovation. Controlling for factors affecting the participation in the procurement market, we attempt to identify the main determinants of firms' propensity to introduce innovations as part of public procurement contracts. We carry out this study by using micro-data from two Community Innovation Surveys for Italian and Norwegian firms. Our findings highlight important differences between firms engaged in regular or innovative public contracts, in particular regarding the role of firm size. Smaller firms find it difficult to enter into the procurement market; however, once doing so, they are characterized by a higher propensity to innovate than their larger counterparts. Major differences between Italian and Norwegian firms concern the innovative activities carried out and the type of cooperation relevant for innovation. In Italy the kind of innovations induced by public procurement seem more incremental and thus new to the firms (and to the public buyers) but not for the market, whilst in Norway procurement-related innovation appears more aimed at introducing market novelties.

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1. Introduction

Public procurement (or PP henceforth) is the purchase of goods and services by governments and state-owned companies. During the last fifteen years, both at the European and national levels, it has been intensely revitalised as a demand-side policy instrument to foster innovation. Particularly the European Union (EU) has adopted revised PP directives, 2014/24/EU and 2014/25/EU, which have provided a new legal framework in order to promote the procurement of innovations. Instead of rigid tender specifications, the new directives favour functional specifications, which provide more flexibility to suppliers to come up with innovative ways of solving a problem or meeting public needs. Furthermore, procurers are encouraged to use life-cycle cost considerations (in which innovative products are proved to be superior), rather than deciding uniquely on the basis of initial purchasing costs as in traditional tenders, where the lowest bid wins the public contract (Czarnitzki et al., 2018). Hence, under the new regulation, innovative solutions and not yet invented or developed technologies can be an explicit part of the contractual arrangements of the procurement process.

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Such a renewed attention can also be found in many documents and initiatives of the European Commission: these have been directed to closely monitoring national policy frameworks and spending on innovation procurement across Europe (cf. EC, 2016) as well as to encourage public buyers of goods and services to use public procurement as a means to stimulate innovations (EC, 2018).

Not surprisingly, a growing attention is paid to promote the involvement of Small and Medium-sized Enterprises (or SMEs henceforth) in the public sector market place. Indeed, given the centrality of SMEs to employment creation, entrepreneurship and economic growth in many countries, the concern for their under-representation in the PP market has increased the adoption and diffusion of SME-friendly procurement provisions. In this regard, for instance, besides the guide on public procurement as a driver of innovation in SMEs (European Commission, 2014), we can recall some specific provisions included in the aforementioned 2014 EU directives, such as the open encouragement to dividing large size PP contracts into lots and the requirement of a detailed justification if that is not possible.

The mounting interest in the use of PP as innovation policy tool is mainly due to the fact that supply-side innovation policies (R&D public subsidies and tax incentives) are deemed to be insufficient to meet the current challenges in promoting competitiveness, also because of increasing budgetary constraints. Nonetheless, however, "there is very limited statistical evidence on the link between public procurement and innovation" (cf. Appelt and Galindo-Rueda. 2016, p. 6). Still in the early 2000s, the empirical literature on public procurement for innovation was rather fragmented and mostly limited to case studies (e.g. Edquist et al., 2000; Edler et al., 2005). Only recently, some studies based on sound statistical and/or econometric evidence have been published (e.g. Aschhoff and Sofka, 2009; Guerzoni and Raiteri, 2014; Uyarra et al., 2014; Slavtchev and Wiederhold, 2016; Reijonen et al., 2016; Ghisetti, 2017; Saastamoinen et al., 2017; Flynn and Davis, 2017; Czarnitzki et al., 2018; Florio et al., 2018; Fernàndez-Sastre and Quizhpi, 2019).

To contribute to this relatively under-researched topic, in this paper we carry out a micro-econometric analysis with the aim of identifying the main determinants of firms' participation in public procurement for innovation (or PPfI henceforth) compared to regular (not involving innovation) public procurement (or RPP henceforth), and therefore to provide a broad characterisation of the firms engaged in innovation activities entailed by public procurement as opposed to firms that only obtain traditional procurement contracts.

We conduct this study by using micro-data from two Community Innovation Surveys carried out in Italy and Norway, which have released information on firms having public procurement contracts. As for Italy, the Italian National Institute of Statistics (ISTAT) has provided the dataset concerned

with the year 2012. With regard to Norway, the analysis is based on more recent micro-data provided by Eurostat, which refer to 2014. As we shall see, we analyse Italian and Norwegian firms using an identical set of explanatory variables that influence, first, the probability of participating in public procurement (regardless the type, innovative or not) and, then, that of being involved in PPfI. This allows us to examine whether some potential determinants of PPfI at the firm level are the same in two very different institutional and economic contexts.

We improve the research stream on the link between public procurement and innovation in the following ways. First of all, we provide a new angle on the relation between public procurement and innovation. Indeed, our focus is on the factors affecting the likelihood of firms' involvement in PPfI compared to RPP, rather than on examining the contribution of public procurement to firms' innovation success in terms of increased innovation inputs or outputs. So far, the available empirical studies have analysed public procurement from this latter standpoint, whilst less attention has been paid to the question of what strategies or firms' characteristics increase the probability that firms will introduce innovations as part of PP contracts. In addressing this issue, we pay specific attention to SMEs: indeed, while the barriers experienced by SMEs are well documented (e.g. Uyarra et al., 2014), the same cannot be said of the factors enabling their participation in PP, as there are fewer studies providing insights about what features or actions effectively promote SMEs' involvement in PP (e.g. Saastamoinen and Reijonen, 2014; Reijonen et al., 2016; Flynn and Davis, 2017). Most importantly, to our knowledge, no previous research has focused on factors explaining SMEs' involvement in PPfI compared to RPP contracts.

Furthermore, by using the CIS 2012 and 2014 micro-data at our disposal, we gain some accuracy on the PPfI indicator as we are able to employ a dummy variable reporting whether a firm has been engaged in any innovation activity related to a public procurement contract or not. Indeed, because other surveys do not contain similar specific questions about innovative public procurement, most previous studies (e.g. Guerzoni and Raiteri, 2015; Fernàndez-Sastre and Quizhpi, 2019) are based on proxies.

Finally, another original aspect of our paper is that it investigates the determinants of firms' participation in PPfI by making a comparison between a country, Italy, that still does not have a comprehensive public procurement strategy for innovation, and another country, Norway, which, instead, is at the forefront of the PPfI development. So far, little attention has been devoted to comparing specific factors or firms' characteristics enabling the participation to PP across different national contexts. Therefore, comparative analyses are needed to get more reliable knowledge about the policy measures that can improve firms' ability to take part in innovative PP contracts.

The remainder of the paper is organised as follows. In Section 2 we outline the key concepts, discuss the theoretical and empirical backgrounds of the present study, and define the main research hypotheses to be tested. Section 3, after presenting some descriptive statistics for the Italian and Norwegian firms involved in PP (and PPfI in particular), illustrates the econometric approach and the explanatory variables used in the subsequent empirical analysis. Section 4 compares the results achieved for Italian and Norwegian firms. Section 5 contains some concluding remarks.

2. Public procurement for innovation

2.1 Key concepts

In its standard definition, "innovative" PP 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 (cf. Edquist and Zabala-Iturriagagoitia, 2012). As such, this is usually opposed to "regular" PP, which takes place when a public body buys goods and services that already exist.

A bit more refined classification is provided by the European Commission, which distinguishes between "Pre-commercial Procurement" and "Public Procurement of Innovative Solutions". In the first case, public buyers purchase R&D services that are likely to give rise to entirely new goods or services. 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" (EC, 2014, p. 12). This is particularly important for SMEs: by providing stable and predictable sources of demand, such PP contracts allow them to make plans for the future, i.e. expand investments in new technologies, capital equipment and human resources (Flyinn and Davis, 2017).

In line with Obwegeser and Müller (2018), who provide a comprehensive review of the empirical literature on this topic, in this paper we refer to a broader concept which they label as "Public Procurement for Innovation"[1]: according to such definition, PPfI does not necessarily refer to entirely new products, but also entail the development of existing products and production processes into new areas or applications. Instead, the standard definition substantially neglects process innovations and, most importantly, those innovations that are incremental in nature, as based on the recombination of existing goods and services (Uyarra and Flanagan, 2010). Therefore, in our perspective, PPfI does not only trigger but also respond to innovation by "favouring goods or services, which have innovative characteristics" (Georghiou et al., 2014, p. 2). As recently stressed by Uyarra et al. (2017; p. 4) "adopting a broad definition is vital, since […] much procurement related innovation at the local and regional level is incremental and of a responsive nature rather

[1] According to Obwegeser and Müller (2018; p. 5), the concept of "public procurement for innovation" addresses the issue of "How can public procurement drive innovation?" while that of "innovative public procurement" refers to the question of "How can public institutions procure innovatively?".

than radical". In the same vein, the micro-econometric analysis carried out by Czarnitzki et al. (2018) shows that PPfI increases the turnover of German firms with product and services not radically new, i.e. new to the firms but not to the market.

2.2. Theoretical and empirical backgrounds

From a theoretical point of view, the discussion on PPfI is intrinsically linked to the debate on the role of demand as a driver of innovation. Scholars embracing the demand-pull approach have always emphasized the importance of demand dynamics as a crucial factor influencing both the decision of firms to innovate and the direction of innovative efforts. The intuition regarding the role of demand for innovation has been sparked by the seminal contribution of Schmookler (1966), who claimed that demand conditions crucially influence the desirability and realization of innovations: indeed, the existence of an expected profitability through market expansion represents the key stimulus to which innovative firms actually react. However, since the 1980's, the focus of the literature has shifted in favour of supply-side factors. Only more recently, in particular with the work by Edler and Georghiou (2007), the long debate between the supply-push versus demand-pull sources of innovation has settled for a more balanced view, which sees demand as a complementary factor driving innovation. According to Guerzoni (2010), this recent wave of studies is characterised by the mixture of two elements. On the one hand, the extent of demand, possibly measured by the size of the market, can be considered as a major incentive for firms to invest in innovative activities. On the other, demand can also be considered as a relevant source of information from users that, by providing producers with more accurate knowledge about the market needs, may substantially contribute to reduce the inherent uncertainty associated with the development of new products.

As already mentioned, in this paper we provide a new perspective on the relation between public procurement and innovation by focusing on factors affecting the likelihood of firms' involvement in PPfI compared to RPP. So far, the existing empirical studies have examined the contribution of public procurement to firms' success in terms of increased innovation inputs or outputs, whilst less attention has been paid to the critical factors increasing the probability that firms will introduce innovations as part of PP contracts.

As far as our knowledge is concerned, Czarnitzki et al. (2018) is the only previous study based on quantitative analysis that actually differentiates between innovative and regular procurement contracts, particularly by taking into account whether legal frameworks allow the functional specifications of public tenders with a view of stimulating the provision of innovative solutions. In particular, to assess the link between public procurement and innovation, the authors have

employed the 2013 wave of the German part of the CIS, the Mannheim Innovation Panel, to investigate the effectiveness of demand-side innovation policies, including public procurement. Although the European reforms adopted in 2014 are subsequent to that period of analysis (2010-2012), they have exploited the fact that Germany had already adopted a similar regulation in 2009. Their results show a positive impact of PPfI on firms' turnover from new products and services and a non significant effect of RPP, which therefore supports the effectiveness of the new regulation in stimulating firms' innovation activities.

In the present paper, by using the CIS 2012 and 2014 micro data at our disposal, we have been able to employ the same direct indicator of PPfI as Czarnitzki et al. (2018). In this respect, it should be stressed that, at least for the EU countries, survey data with information on innovative public procurement have become available from CIS 2012. Other innovation surveys (included the CIS before 2012) do not include specific questions about PPfI. It follows that most previous studies are based on proxies, which do not allow one to disentangle the direct and indirect effects of public procurement on innovation. For instance, a recent study by Fernàndez-Sastre and Quizhpi (2019) has employed the 2009-2011 data from the Ecuadorian Survey of Innovation and the Ecuadorian National Services of Public Procurement to evaluate the impact of RPP (at that period Ecuador did not have any PPfI program) on firms' decision to invest in R&D. Although regular procurement activity may in itself be capable of indirectly spurring innovation[2], the authors have not found evidence of any significant effect on firms' R&D expenditure. In another study, Guerzoni and Raiteri (2015) have attempted to capture the effect of the direct procurement of innovative goods and services by exploiting the information provided by the 2006-2008 Innobarometer Survey for 27 EU Member States. This survey explicitly asks firms not only to indicate any public procurement contracts they have been awarded, but also whether such contracts provided them with an opportunity of selling an innovation, which has allowed to construct a binary indicator for firms involved in innovation-related procurement. The authors have found evidence that innovative procurement has a greater effect on firms' R&D efforts compared to R&D subsidies or tax incentives. Nevertheless, although we agree that this indicator represents a substantial improvement compared to previous studies based upon RPP only, we contend that a direct link with firms' innovation activities cannot be taken for granted.

For Italy, the period of analysis of our paper (2010-2012) precedes the 2014 EU revision of PP regulations. In any case, although the government had not adopted a comprehensive strategy to

[2] Cabral et al. (2016) distinguish three kinds of indirect effects of PP on innovation: (I) by enlarging the size of the market for new goods, thus providing firms with the necessary incentives to invest in R&D; (II) by fostering the adoption of new standards; (II) by affecting the competitive structure of the market to make it more conducive to innovation. See also Uyarra and Flanagan (2010) for a broader discussion of the direct and indirect effects of PP on innovation.

foster innovation via PP (cf. Appendix 1), the Italian firms show a non-negligible involvement in PPfI (see Section 3). Indeed, in Italy, 4% of the firms surveyed in CIS 2012 had been involved in PPfI (corresponding to 16% of the firms with PP contracts) while in Germany, always between 2010 and 2012, the same share was equal to 3% (15% of the firms engaged in PP) (see Czarnitzki et al., 2018). The current Norwegian legislation on public procurement is also based on the 2014 EU Directives. Norway, however, had already garnered a long experience in supporting innovative public procurement by undertaking numerous measures that, over time, have given rise to a coherent strategy (cf. Appendix 1). It is thus not surprising that, according to our descriptive evidence (see Section 3), Norway turns out far ahead of Italy (and Germany) in terms of firms' participation in PPfI, which account for more than 8% of the firms involved in CIS 2014 sample (up to 25% of the firms with PP contracts)[3]. This allows us to examine whether some potential determinants of PPfI at the firm level are the same in two very different economic and institutional contexts (see Appendix 1).

Another relevant issue, stressed by scholars and policy makers, is the uneven presence in the PP market of firms with different size. According to a study carried out on behalf of the European Commission (GHK, 2010), smaller businesses are "disadvantaged" in that they do not achieve a percentage of public procurement contracts proportionate to their economic importance. However, innovative SMEs can find an important source of demand in the public sector and, therefore, improve the innovation potential of public procurement (see, among others, Reijonen et al., 2016; Flynn and Davis, 2017; Saastamoinen et al., 2018). As highlighted by OECD (2018: p. 42), "the level of innovative SMEs participation in public procurement market, though being still relatively low, is higher than that for general SMEs population". For instance, in the case of Norway (data for Italy are missing) around 38% of innovative SMEs are involved in PP contracts while the share reduces to 22% for those without innovations (cf. OECD, 2017b; p. 159). To overcome such a market failure, several measures can be (and are being) undertaken to give SMEs a better access to the PP markets as well as to remove the barriers they face to win public contracts (for a recent and comprehensive survey see OECD, 2018). In light of this, identifying the critical factors that increase the likelihood that firms (especially those of smaller size) will get access to the procurement markets and obtain PPfI contracts becomes of paramount importance.

[3] By looking at the available 2014 CIS micro-data for another Nordic country, Finland, we can see that, like in Norway, the share of firms participating in PPfI is considerably higher than in Italy and Germany (up to 8.7% of total firms and 26% of those involved in PP; see Statistics Finland, 2016). However, it should be stressed that, like the correspondent CIS wave for Germany used by Czarnitzki et al. (2018), the Finnish survey does not include firms in the construction sector, which are instead widely covered in both the Italian and Norwegian CIS datasets under consideration.

2.3 Research hypotheses

Overall, despite the existing evidence points to the effectiveness of PP in stimulating innovation, it is widely acknowledged that a number of barriers can prevent some firms from even entering the PP markets, particularly when innovation represents the specific object of the procurement contract. Important barriers can be related, on the one hand, to the firms' awareness of innovation opportunities and their capabilities to seize them and, on the other, to the inherent risk aversion of public officials (see Uyarra et al., 2014).

In principle, in comparison with the procurement of already existing goods and services for the lowest possible price, PPfI should require a higher degree of competence both within public administrations and firms. As for the firms, obtaining an PPfI contract would require a certain degree of "innovative work" to fulfil the demand of the public buyer and therefore the capacity to mobilise all their internal (human and financial) resources not only to identify the innovation opportunities, satisfy onerous qualification criteria and go through the procedural hurdles of public sector tendering, but also (and most importantly) to reach the goal of formulating a value proposition that satisfies the expectations of the purchasing organisation (Flynn and Davis, 2017). It follows that, compared to firms with regular PP contracts, those dealing with PPfI should have a greater human capital endowment and invest more in innovative activities (i.e. aimed at developing new products and/or processes).

At the same time, the inherent risk aversion of public agencies might result into selection criteria that privilege firms with larger size and a longer experience as public administrations' providers. Thus, due to presence of rules that favour incumbent firms, even innovative SMEs could find it difficult to win a PP contract. As a consequence, for a rigorous assessment of the factors facilitating firms' involvement in PPfI, it is important to take into account the possible barriers that small businesses have to face in order to enter into the PP market, irrespective of whether the procurement contracts entail innovation or not. The econometric approach that we adopt (see Section 3.2 below) is adequate to test whether SMEs are less likely to participate in both regular and innovative PP.

A further key factor that cannot be neglected in this kind of analysis is the importance of information coming from sources external to the firms. First, external knowledge might substantially contribute to increase the general information and awareness of firms about the availability and potential advantages of this particular form of public support. Indeed, it is widely acknowledged that inadequate information not only on procurement opportunities and benefits, but also about the procurement process itself (i.e. its regulation, requirements and procedures), is among the major obstacles to SMEs' participation in PP (Nicholas and Fruhumann, 2014). Secondly, firms with wider access to multiple sources of external knowledge should also be in a

better position to offer innovative solutions. This should diminish the risk aversion of contracting authorities and create an environment of trust that, in turn, could increase firms' ability to enter into the market of PPfI. As stressed by Saastamoinen et al. (2017), inter-organisational networks can be seen as means to extend SMEs' resources and capabilities to compete for public tenders, though very little is known about how such firms actually use these networks in the context of PP for innovation.

The above arguments lead us to test the following hypotheses:

Hypothesis 1a: firms with greater endowment of human capital (i.e. graduated employees) are more likely to be engaged in PP for innovation rather than regular PP activities;

Hypothesis 1b: firms investing in in innovative activities (i.e. aimed at developing new products and/or processes) are more likely to undertake PPfI than RPP contracts;

Hypothesis 2: large firms are more likely to obtain both PPfI and RPP contracts;

Hypothesis 3: the more firms are open to frequent interaction with different external actors and sources of knowledge, the higher the likelihood they will come up with innovations induced by PP contracts.

3. Empirical analysis

3.1 Descriptive statistics on firms involved in PPfI

By using the CIS micro-data at our disposal, in this section we provide a broader characterisation of the Italian and Norwegian firms carrying out innovation as part of PP contracts compared to those participating in regular PP as well as those not involved in PP.

Drawing on the firms' answers to the CIS questionnaires, we have been able to construct the two key dependent variables of our analysis. The first one, *Public Procurement*, is a binary indicator equal to 1 if a firm has declared to have any PP contract (i.e. in general, without specifying whether involving innovation or not)[4]. Then, we have built a second dummy variable, *Innovative Public Procurement for Innovation* (henceforth PPfI), for firms declaring to develop innovations as part of PP contracts[5].

Appelt and Galindo-Rueda (2016) report that between 9% and 34% of firms operating in countries for which data are available (most of them coming from CIS 2012) have delivered goods or services to public authorities. Table 1 shows that the two countries under exam are among the top performers, even though, as already mentioned, Norwegian firms participate in PP more frequently (34%) than firms in Italy (27.5%).

The last row of the table reports that in both countries the large majority of firms with PP contracts have not developed innovations in connection with such contracts. This does not exclude that such firms have introduced some kind of innovation in an autonomous way: in fact, 43% of the Italian firms with regular PP contracts can be classified as innovative since they have introduced new products or processes during the period of reference; the same occurs to almost 45% of firms with regular PP in Norway. Thus, having stressed that the firms with regular PP contracts could also be innovative, our analysis is focussed on those involved in PPfI, i.e. the firms whose innovations have been induced by PP contracts, because either explicitly required or important for the awarding of such contracts.

[4] Within the section on public procurement of the CIS 2012 and 2014, the first question reads "During the three years 2010 to 2012 (or 2012 to 2014) did your enterprise have any procurement contracts to provide goods or services for domestic or foreign public sector organisations?"

[5] The second question reads: "Did your enterprise undertake any innovation activities as part of a procurement contract to provide goods or services to a public sector organisation?"

Table 1: Firms involved in RPP and PPfI: absolute value and percentages on total firms

	Italy (CIS 2012)	Norway (CIS 2014)
Total number of firms	18697	4974
Firms with Public Procurement	5137 (27.47)	1691 (34.00)
Firms with Regular Public Procurement	4303 (23.01)	1265 (25.43)
Firms with Public Procurement for Innovation	834 (4.46)	426 (8.57)

Source: own computations on CIS 2012 Italian and CIS 2014 Norwegian data.

Considering the firms involved in PPfI, the share in Norway (8.6%) is almost twice than that recorded in Italy (4.6%). Such a big difference could be due, among other things, to the fact that in Norway, as opposed to Italy, the policy goal of inducing innovations via PP contracts has been prioritised by the government (cf. Appendix 1) and pursued with greater determination and effectiveness.

Table 2: Firms involved in PP and PPfI: absolute values and percentages by size class*

	Italy (CIS 2012)				Norway (CIS 2014)			
	Small	Medium	Large	Total	Small	Medium	Large	Total
Total firms	13246	3636	1815	18697	2580	1972	422	4974
Firms with PP	3529	1040	568	5137	766	730	195	1691
Firms with PPfI	423	217	194	834	199	168	59	426
Percentage of firms with PP (on total firms)	26.64	28.60	31.29	27.47	29.69	37.02	46.21	34.00
Percentage of firms with PPfI (on firms with PP)	11.99	20.87	34.15	16.24	25.98	23.01	30.26	25.19

Source: own computations on CIS 2012 Italian and CIS 2014 Norwegian micro-data.
*Small: firms having between 10 and 49 employees. Medium: firms having between 50 and 249 employees. Large: firms with more than 249 employees.

With respect to the role of firm size in PP participation, there is ample international evidence that SMEs find it difficult to enter into the PP markets (see Section 2.2). CIS micro-data for Italy and Norway confirm this finding (cf. Table 2). Indeed, as for firms participating in PP, in both countries, the share is bigger for large firms than for those of medium-size and, especially, for small firms. Nevertheless, looking at the Norwegian firms involved in PPfI, the differences between size classes are by far less pronounced: indeed the share of small firms with PPfI (26%) is higher than that of medium-sized firms (23%) and not so far from that of large companies (30%). In Italy, instead, the percentage of firms with PPfI is remarkably higher in large as opposed to smaller

companies. This could suggest that, in Italy, small and medium-sized firms are even more discriminated when PPfI is taken into account. However, such a conclusion cannot be inferred from a simple (univariate) descriptive analysis. In order to ascertain this hypothesis, it is necessary to perform an econometric analysis able to control for other firm characteristics that are likely to affect, first, the participation in PP and, then, the involvement in PPfI activities (cf. Section 3.2).

Table 3 reports the firms' distribution across six aggregate sectors[6]. Sectorial aggregations are based on the two-digit NACE (Statistical Classification of Economic Activities). With respect to high- and low-tech industries, we have followed the OECD ISIC Rev. 3 technology intensity definition of manufacturing industries (OECD, 2011). In particular, we have grouped together firms in high and medium-high technology industries into the unique category of *High-tech industry;* likewise, firms in low- and medium-low technology industries have been grouped together in *Low-tech industry*. In order to identify firms in *Knowledge intensive business services* (*KIBS*) and keep them separated from those in other, traditional or less knowledge intensive services, we have referred to the Eurostat classification[7]. Along with *Other services*, the remaining sectors are *Construction* and *Trade*.

According to Table 3, both in Italy and Norway, firms involved in PP are mostly in Construction, followed by KIBS and Other services. Only in Norway, the share of firms with PP is very high also in Trade. As for firms involved in PPfI, in Italy High-tech industries and KIBS are largely predominant, with shares equal to about 31% of the firms with PP contracts, while the same percentages are lower in the other sectors, though especially in Construction and Trade. Also in Norway, firms with innovations performed as part of PP contracts are more concentrated in KIBS (35.5%) and High-tech industries (33.6%). With the partial exception of Low-tech industries, all the other sectors record much lower percentages. Thus, in both countries, the sectorial characteristics of the firms with PP contracts are significantly different from those of the firms involved in PPfI.

[6] To get more meaningful information from our estimates, we prefer to employ few aggregate sectors rather than a very high number of two-digit industries.

[7] See http://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf.

Table 3: Firms involved in PP and PPfI: absolute values and percentages by industry

	High-tech industries	Low-tech industries	Construction	Trade	KIBS	Other services	Total
Italy							
Firms with PP	236	436	1959	1072	740	694	5137
Firms with PPfI	73	76	189	135	230	131	834
Percentage of firms with PP (on total firms)	20.42	14.16	45.06	19.87	30.71	30.08	27.47
Percentage of firms with PPfI (on firms with PP)	30.93	17.43	9.65	12.59	31.08	18.88	16.24
Norway							
Firms with PP	122	255	248	188	549	329	1691
Firms with PPfI	41	60	39	32	195	59	426
Percentage of firms with PP (on total firms)	26.35	20.21	51.35	44.03	42.46	31.95	34.00
Percentage of firms with PPfI (on firms with PP)	33.61	23.53	15.73	17.02	35.52	17.93	25.19

Source: own computations on CIS 2012 Italian and CIS 2014 Norwegian micro-data.

3.2 Econometric strategy

Moving to the econometric method, our analysis is based upon a Heckman probit model with sample selection. Such a model is composed of two probit equations: an outcome equation for the probability of introducing innovations as part of PP contracts (PPfI), and a selection equation for the probability of being involved in PP. Formally:

$$PPfI_i = 1(\boldsymbol{X}_i'\beta + \epsilon_i > 0) \;\; if\; PP_i = 1,\; missing\; otherwise \qquad [1]$$

$$PP_i = 1(\boldsymbol{Z}_i'\alpha + u_i > 0) \qquad [2]$$

where the suffix *i* identifies firms.

Thus, the firm characteristics that increase the PP participation are used to correct the estimation of the probability of being involved in PPfI. Despite the parameters of the model are identified even when the same set of regressors enters the selection and outcome equations (i.e. $\boldsymbol{X_i}$ and $\boldsymbol{Z_i}$ include the same variables), to improve identification it is a standard practice to use different covariates in the second equation (selection), which must be unrelated to the innovation probability (outcome).
Then, the model can be estimated with Maximum Likelihood (ML) either simultaneously (one-step) or with a two-step procedure.

We test this model on the total sample of Italian and Norwegian firms by using an identical set of regressors, which allows us to examine whether some potential determinants of PPfI at the firm level are the same in two very different institutional and economic contexts. In addition, to better focus on factors predicting SMEs' participation in PPfI, we repeat the estimations by excluding large firms from both samples.

3.3 Explanatory variables

Among the independent variables that are used in both the selection (PP participation) and outcome equation (PPfI involvement) we consider: two dummy variables for *small firms* (having between 10 and 49 employees) and *medium-sized firms* (from 50 to 249 employees), with *large firms* taken as reference category; and five dummy variables for the firms' sectors (see Table 3), with *Other services* as reference.

Then, there is a set of variables affecting only the probability to innovate. Among these, we have included a variable routinely used in empirical studies on innovation: *Human capital*, measured by an ordinal indicator taking values from 0 to 6 according to the percentage of employees with an university degree[8]. Next, there are two synthetic measures of cooperation for innovation: *Cooperation with universities and public research institutes* and *Cooperation with other external actors (suppliers, customers, etc.)*. These are obtained through a principal component analysis (PCA) of seven binary indicators identifying different patterns of cooperation for innovation according to the type of firms' partners (cf. Appendix 2)[9].

Two further explanatory variables have been also obtained by processing with PCA seven dummy variables accounting for the type of innovative activities carried out by the firms[10]: *Innovative activities mainly devoted to process innovation,* a synthetic indicator for the acquisition of new machinery and external knowledge and the presence of personnel training for innovation; and *Innovative activities mainly devoted to product innovation,* which instead refers to product design and marketing activities for the introduction of innovations as well as internal R&D activities.

Finally, there is the set of variables affecting only the probability of PP participation. *Firms belonging to a group* is a dummy variable that takes value 1 if a firm belongs to an enterprise group. Here, the hypothesis to be tested is that group-affiliated firms have a greater potential to win

[8] The classes are the following: 0 stands for none graduated employees; 1 for less than 5%; 2 for 5 to 9%; 3 for 10-24%; 4 for 25-49%; 5 for 50-74% and 6 for 75% and more.

[9] The types of partners for cooperation considered are: other firms within the group; suppliers; private customers; competitors; consultants; universities; government or public research institutes. Details on the PCA are provided in Appendix 2.

[10] The types of innovative activities taken into account are: R&D intra-muros; acquisition of machinery; acquisition of external knowledge; training for innovative activities; marketing activities for the introduction of innovations; product design activities; other innovative activities. Appendix 2 describes the PCA applied to these binary variables.

PP contracts. *Firms operating in domestic market only* is equal to 1 if a firm has declared to sell its products in the domestic market only. This variable should positively affect PP participation because in any country the bulk of PP is undertaken at local level and involves domestic firms. *New ways of organising external relations* is also a binary indicator used to identify firms having introduced organisational innovations facilitating their external relations. By capturing a firm's attitude and efforts to undertake alliances or collaborations with other enterprises, this variable should also exert a positive impact on PP.

4. Results

Table 4 reports the results of the described econometric analysis for Italy and Norway, namely the Heckman probit simultaneous estimation for the probability of being engaged in PPfI. Next, Table 5 shows the results obtained by excluding large firms, and thus focusing on the sub-samples of Italian and Norwegian SMEs[11].

Starting from Table 4, as the bottom lines of the table report, for both countries the hypothesis of independent equations is refused by the Wald test, which confirms that the outcome and selection equations should not be separately estimated. Moreover, the negative and significant athrho (i.e. the negative correlation between the error terms of equations 1 and 2) suggests that there are some un-observables firm characteristics that increase the probability of PP participation while reducing the likelihood of PPfI. To summarize, any estimate of the determinants of PPfI involvement without controlling for sample selection would turn biased results.

Table 4: Heckman probit model with sample selection: one-step simultaneous estimation

	ITALY (CIS 2012)		NORWAY (CIS 2014)	
	PPfI (outcome eq.)	PP (selection eq.)	PPfI (outcome eq.)	PP (selection eq.)
Cooperation with universities and public research institutes	-0.0187 (0.0130)		0.0882** (0.0358)	
Cooperation with other external actors (suppliers, competitors, etc.)	0.0208*** (0.0067)		0.0442** (0.0180)	
Innovative activities mainly devoted to process innovation°	0.1008*** (0.0169)		-0.0033 (0.0284)	
Innovative activities mainly devoted to product innovation°°	-0.0068 (0.0108)		0.1571*** (0.0505)	
Human capital (ordinal, values 0 to 6)	0.0116 (0.0073)		0.0213 (0.0240)	
High-tech manufacturing industries	0.2253** (0.0894)	-0.3833*** (0.0528)	0.0988 (0.1293)	-0.1852** (0.0776)

[11] Consistent results are achieved by running two-step estimations. See Appendix 3.

Low-tech manufacturing industries	0.3569***	-0.5219***	0.1690	-0.3465***
	(0.0868)	(0.0402)	(0.1328)	(0.0575)
Knowledge intensive business services	0.0270	-0.0221	-0.0694	0.3005***
	(0.0494)	(0.0391)	(0.1237)	(0.0542)
Trade	0.1228**	-0.2700***	-0.3006**	0.3651***
	(0.0604)	(0.0340)	(0.1175)	(0.0732)
Construction	-0.4961***	0.4688***	-0.2607*	0.5634***
	(0.0414)	(0.0344)	(0.1516)	(0.0712)
Small firms	0.2405***	-0.2770***	0.3129**	-0.4594***
	(0.0560)	(0.0406)	(0.1228)	(0.0687)
Medium-sized firms	0.1557***	-0.1298***	0.0999	-0.2324***
	(0.0493)	(0.0400)	(0.1062)	(0.0683)
Firms belonging to a group		0.0467**		-0.0016
		(0.0227)		(0.0445)
Firms operating in domestic market only		0.0490**		-0.0544
		(0.0210)		(0.0400)
New ways of organising external relations		0.3800***		0.2836***
		(0.0649)		(0.0594)
Constant	0.3934***	-0.4437***	0.0231	-0.1705**
	(0.0930)	(0.0589)	(0.3437)	(0.0848)
Wald Chi2(1) test of independent equations (rho=0)	18.36***		4.06**	
athrho	-2.0080***		-1.0865**	
Observations	18,697		4,974	
Censored obs. (firms without PP contracts)	13,560		3,283	
Uncensored obs. (firms with PP contracts)	5,137		1,691	

Robust standard errors in brackets. Large size and Other services, among firm size and industry dummies, used as reference category. *** p<0.01, ** p<0.05, * p<0.10. °=Acquisition of machinery; acquisition of external knowledge; training for innovative activities. °°=Product design activities; marketing activities for the introduction of innovation; R&D intra-muros.

Starting from the selection equation and looking at the specific determinants of PP (bottom parts of the third and fifth column), only the variable accounting for the implementation of organisational innovations impacting firms' external relations plays a pervasive role, being positive and highly significant in both countries. This finding confirms that investing in new forms of external relations may facilitate the access to PP markets. Moreover, for the same goal, the improvement of external relations is useful to acquire more information and knowledge. This is further supported by the positive and significant coefficient arising for group membership, though, in this case, only for Italy. For the same country, also the exclusive reliance on domestic market increases the likelihood of PP participation by firms.

Moving to the innovation equation and looking at the specific determinants of PPfI (top parts of the second and fourth column) we find that, contrary to our expectations, in both countries, to have a high level of human capital does not play a significant role. Therefore, Hypothesis 1.a is not

supported: a greater endowment of graduated employees does not improve firms' ability to innovate *via* public contracts.

In line with Hypothesis 1.b, instead, firms' investing in innovative activities are confirmed to be more involved in PPfI rather than RPP activities. In this respect, an important difference between Italian and Norwegian firms concerns the type of innovative activities emerged as relevant: indeed, across Italian firms we find a positive and significant relationship between performing innovative activities mainly devoted to process innovations (such as acquisition of machinery and personnel training) and the likelihood of being involved in PPfI, whilst the same variable turns out as not statistically significant in Norway; on the contrary, among Norwegian firms the innovative activities mainly devoted to product innovations (such as product design, marketing and R&D) are more conducive to PPfI, while in the Italian case, the correspondent coefficient is not significant and even negative.

Regarding the variables included both in the selection and outcome equations (central and bottom parts of Table 4), there is a highly significant and negative association between being either a small or a medium-sized firm and PP participation, which confirms the difficulties that SMEs face to enter into PP markets (cf. Section 2.2). Nevertheless, moving to the outcome equation, a very important result that we find, in contrast with our expectations (Hypothesis 2), is that smaller firms, as opposed to large companies, are more likely to undertake innovations as part of PP contracts. In the Italian case, both small and medium-sized firms have a higher probability to be involved in PPfI, while in Norway the same occurs to small firms only (the estimated parameter for medium-sized firms is positive but not statistically significant). Accordingly, and to put it in a way consistent with the adopted econometric strategy, it is possible to say that, once smaller businesses have managed to access the PP market, they are not less able to participate in PPfI than their larger counterparts. Indeed, innovative SMEs probably compensate for size related disadvantages with greater adaptability and flexibility.

Turning to sectorial differences, in both countries a mounting role for PP participation is played, as expected, by the construction sector. Instead, compared to other services (reference category), to be a manufacturing firm (high-tech or low-tech) significantly decreases the probability of having PP contracts. In accordance with the suggestions coming from our descriptive analysis (cf. Section 3.1), in Norway trade and knowledge intensive business services are also important; in Italy, instead, being in trade significantly decreases the likelihood of PP participation.

Concerning PPfI, instead, both the Italian and Norwegian firms belonging to the construction industry have a lower probability to take part in it. Only in Norway a similar negative impact arises for trade firms, while other sectors do not exert a significant impact. All in all, in Norway industry

dummies do not reveal remarkable differences across industries for what concerns the likelihood of firms' engagement in procurement-related innovation. In Italy, on the contrary, industry dummies indicate that firms involved in PPfI are not only in high-tech manufacturing but also in trade and, most importantly, in low-tech manufacturing industries, while the parameter for construction firms is negative.

Broadly confirming Hypothesis 2, we find a positive role of external cooperation in increasing firms' participation in PPfI. Accordingly, firms open to frequent interaction with various sources of external knowledge are more likely to offer innovative solutions through PP. More in detail, a positive and significant effect of that undertaken with universities and government/public research labs emerges only for Norway, whilst in Italy it turns out to be negatively associated with PPfI. Cooperation with other external actors (such as suppliers and competitors), instead, increases the likelihood of PPfI in both countries, though the impact appears stronger for Italy. This is in line with Saastamoinen et al. (2018) who show that, for Finnish SMEs, networks with other firms, rather than with public and private R&D organizations, increases the probability of introducing innovations via PP.

Taken together these findings - particularly the positive role of being engaged in activities mainly devoted to process innovation and the non-significant impact of cooperation with scientific institutions - may suggest that in Italy the kind of innovations induced by, or connected with, PP contracts are not too complex or radical in nature: more likely, they are incremental and/or related to goods and services that, although new to the firms and also new to the public bodies that buy them, are not really new to the markets (Uyarra and Flanagan, 2010; Uyarra et al., 2017; Czarnitzki et al., 2018). In the Norwegian case, instead, our main findings - the positive role of being engaged in activities mainly devoted to product innovation as well as of cooperation with universities and public research labs - may lead to think that the innovations induced by PP are perhaps more relevant and thus, at least to some extent, linked to market novelties.

Table 5: Heckman probit model with sample selection: one-step simultaneous estimation (SMEs only)

	ITALY (CIS 2012)		NORWAY (CIS 2014)	
	PPfI (outcome eq.)	PP (selection eq.)	PPfI (outcome eq.)	PP (selection eq.)
Cooperation with universities and public research institutes	-0.0123 (0.0163)		0.0562* (0.0336)	
Cooperation with other external actors (suppliers, competitors, etc.)	0.0280*** (0.0101)		0.0507** (0.0218)	
Innovative activities mainly devoted to process innovation°	0.1142*** (0.0242)		-0.0077 (0.0283)	
Innovative activites mainly devoted to product innovation°°	-0.0112 (0.0123)		0.1363** (0.0544)	

Human capital (ordinal, values 0 to 6)	0.0115 (0.0077)		0.0273 (0.0245)	
High-tech manufacturing industries	0.2323** (0.1089)	-0.3892*** (0.0630)	0.0827 (0.1248)	-0.1135 (0.0807)
Low-tech manufacturing industries	0.3574*** (0.0964)	-0.5100*** (0.0434)	0.1385 (0.1466)	-0.3242*** (0.0608)
Knowledge intensive business services	0.0243 (0.0541)	-0.0344 (0.0428)	-0.1451 (0.1203)	0.3120*** (0.0568)
Trade	0.1145 (0.0723)	-0.2605*** (0.0362)	-0.2989*** (0.1160)	0.3366*** (0.0773)
Construction	-0.4956*** (0.0440)	0.4718*** (0.0361)	-0.2786* (0.1606)	0.5681*** (0.0753)
Small firms	0.0936** (0.0429)	-0.1505*** (0.0289)	0.2252*** (0.0620)	-0.2248*** (0.0411)
Firms belonging to a group		0.0484** (0.0243)		-0.0030 (0.0448)
Firms operating in domestic market only		0.0510** (0.0230)		-0.0568 (0.0416)
New ways of organising external relations		0.3622*** (0.0754)		0.2888*** (0.0710)
Constant	0.5434*** (0.1124)	-0.5728*** (0.0523)	0.2089 (0.4005)	-0.4146*** (0.0648)
Wald Chi2(1) test of independent equations (rho=0)	13.28***		3.45*	
athrho	-1.9950***		-1.2294*	
Observations	16,882		4,552	
Censored obs. (firms without PP contracts)	12,313		3,056	
Uncensored obs. (firms with PP contracts)	4,569		1,496	

Robust standard errors in brackets. Medium-sized firms and Other services, among firm size and industry dummies, used as reference category. *** p<0.01, ** p<0.05, * p<0.10. °=Acquisition of machinery; acquisition of external knowledge; training for innovative activities. °°=Product design activities; marketing activities for the introduction of innovation; R&D intra-muros.

Turning to Table 5, we can see that the results obtained when repeating the estimations by excluding large firms are fully consistent with those already discussed. In particular, we find that smaller firms have lower probability of entering PP markets compared to medium-sized ones. This finding, in line with Flynn et al. (2015), highlights the presence of some heterogeneity also within the sub-sample of SMEs. In this respect it needs to be stressed that we also find significant differences between small and medium-sized firms regarding PPfI participation: in fact, according to our results, small firms appear more advantaged relative to medium-sized firms in introducing innovations as part of PP. As a consequence, although smaller firms may find it difficult entering into PP markets, once doing so, they seem characterised by a higher propensity to be involved in PP for innovation[12].

[12] The two-steps estimation for SMEs reported in Appendix 3 (see Table A2.2) shows almost consistent results. Few differences regard, in particular, the non significant role of being a small firm for PPfI participation though in Italy only,

5. Concluding remarks

The empirical analysis carried out in this paper has shown that there are important differences between the firms that are engaged in regular public procurement and those taking part in public procurement for innovation. These especially regard the role of firm size: the evidence provided confirms that for SMEs it is more difficult to enter into PP markets; however, once they have managed to do so, they are characterised by a higher propensity to be involved in innovative PP compared to large firms. Moreover, even small firms (with less than 50 employees) seem to be more propense to introduce innovations as part of PP contracts than medium-sized ones.

Although based on cross-sectional datasets, we contend that these results are not only interesting, but also sufficiently robust in that they arise from two very different economic and institutional contexts: Italy and Norway. From a policy point of view, they reinforce the need of reducing the barriers that prevent SMEs to enter into the PP market and win public tenders. Indeed, levelling the playing field for public procurement represents a crucial condition for allowing smaller and more flexible firms to provide the public administrations with innovative goods and services. Of course, attracting and supporting higher participation of SMEs in public procurement is not a free lunch. In this respect, for instance, Timmermans and Zabala-Iturriagagoitia (2013) have proposed "coordinated unbundling" as a method to break down large tenders in order to provide a better access to PP for smaller firms. We agree that to divide procurement contracts into smaller parts, or break down tenders geographically, could be useful in order to "provide stimuli to smaller organisations to participate and thereby, indirectly, reserving spots for them in the procurement process." (Timmermans and Zabala-Iturriagagoitia, 2013, p.6).

Furthermore, according to our results, the sectorial characteristics that increase the probability of being involved in public procurement without qualifications (i.e. innovative or not) are remarkably different from those affecting the likelihood of being engaged in public procurement for innovation. As for PP participation in general, the construction sector seems to play the most pervasive role. Focusing on firms' engagement in PPfI, instead, we do not find remarkable differences across industries in Norway while in Italy even the firms belonging to trade and low-tech manufacturing industries have a higher probability to innovate *via* PP.

Regarding the other potential determinants of PPfI, the non-significant role of human capital (i.e. firms' endowment of graduated employees), emerged both in Italy and Norway, may suggest that high levels of this variable could be expected to also facilitate firms' involvement in regular PP activities. Besides this, our results confirm the positive influence of preforming specific activities

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where the correspondent coefficient is however positive; and the coefficient of high-tech manufacturing industries, which in this case turns out not significant in both countries.

aimed at innovation development and, most importantly, the relevance of cooperation with external partners. In this respect, however, some interesting differences have also emerged between Italian and Norwegian firms. Among Norwegian firms, the innovative activities more oriented to product innovations and cooperation with universities and public research labs play a significant role. By contrast, in the Italian case the probability to participate in PP for innovation is more related to the presence of innovative activities mainly devoted to process innovations and of cooperation with other private partners. From the point of view of the related innovation potential, these findings may suggest that in Italy the kind of innovations induced by PP are more incremental in nature, namely new to the firms (and to the public buyers) but not for the market in which they operate, whilst in Norway PPfI contracts are more aimed at encouraging the development of market novelties. Thus, along with a remarkable percentage of firms participating in PPfI (one of the highest in Europe), Norway is also characterized by a greater complexity of innovations related to public procurement.

These different findings for Italy and Norway could be due to several reasons, such as the different firms' propensity to perform R&D activities as well as the different quality and competences of public administrations. However, an important role should also be ascribed to the fact that the Norwegian government, as opposed to the Italian one, has effectively implemented a comprehensive public procurement strategy for innovation.

In any case, it must be pointed out that the Norwegian case represents an exception rather than the rule. Indeed, most of the available empirical evidence for European countries suggests that the innovative solutions stimulated by public procurement contracts are mainly of incremental nature. Hence, European procurement agencies, and especially those operating at the local and regional level, need to be equipped with enough incentives, skills and competences to design and manage public procurement contracts involving also more radical or complex innovations.

Aside from the nature of innovations involved, European central and local governments should increase the diffusion of public procurement as a demand-side measure of innovation policy. In this connection, the possibility of making PP contracts for innovation (especially by using functional specifications), which has been allowed by the EU Procurement Directives of 2014, needs to be more publicized among procurement agencies. In the same vein, innovative firms, and especially SMEs, should increase their awareness and knowledge about the advantages offered by PPfI as a means to increase the provision of new goods and services to public administrations.

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Appendix 1 - Public procurement for innovation in Italy and Norway: institutional and legal framework

The main features of the current Italian model of public procurement dates back to 2000. In 2004, with the aim of fostering e-procurement tools, the Italian government has launched the MePA (Electronic Marketplace for the Public Administration), that is now one of the leading e-marketplaces currently operating in Europe (OECD, 2018), and which has provided a remarkable impulse to SMEs' participation in the market for low-value public contracts (i.e. below the EU threshold). In this respect, it needs to be stressed that, since the late 1990s, thus even before the 2014 European Directives on public contracts, Italy has also undertaken various (direct and indirect) actions to support SMEs' participation in public contracts. Moreover, with the Dlgs. 50/2016, the country has continued the reform of public procurement in line with the 2014 European directives (24/EU and 25/EU). Hence, with respect to the policies for PPfI, in particular, the Ministry of Education, University and Research (MIUR) and the Agency for Digital Italy (AGID) have recently defined a programme for the pre-commercial procurement of R&D and innovation in services. However, aside from this programme and a few experiences at regional level, in Italy there is not a comprehensive national strategy for PPfI (cf. OECD, 2017a). Rather, the bulk of the policy efforts have been focused on rationalising regular public procurement activity: for instance through the institution, since 1998, of Consip S.p.A., a public limited company entrusted to act as the central purchasing agency on behalf of the Italian Government.

Norway's original legislation implementing public procurement has been in force since 1994. However, the Norwegian legislation on public procurement is now, to a large extent, also based on the EU 2014 directives, in accordance with Norway's obligations under the EEA Agreement. In Norway there is no a specific strategy or policy aimed at supporting SMEs' participation in the PP market (OECD, 2018). Despite this, the procurement for innovation has long been a government priority. For instance, since 1968 the country has Public Sector R&D Contracts (OFU), with public funding, where suppliers cooperate with public sector buyers in developing new products or services.

Among the most recent initiatives, the agency for Public Management and eGovernance and the National Programme for Supplier Development have introduced a national method for the procurement of innovation, which provides public buyers with a more harmonised and systematic approach for the procurement of innovation. In addition, Innovation Norway, a state-owned company and innovation development bank, has launched a strategic programme ("Industrial and

Public Research and Development Contracts") to stimulate user-driven innovation based on binding agreements between public bodies and innovative Norwegian firms (OECD, 2017a).

Appendix 2 - Principal Component Analyses: cooperation for innovation and innovative activities

This appendix provides details of the Principal Component Analysis (PCA) that has been used to obtain the synthetic measures of external cooperation, firms' innovative activities and use of external sources of knowledge described in the main text.

Tables A1.1 and A1.2 show the results of the PCA analysis run to identify specific patterns of cooperation for innovation in Italy and Norway, starting from seven binary indicators built according to the information provided by the CIS, namely: *Cooperation within group; with suppliers; private customers; competitors; consultants; universities; government or public research labs*. Not surprisingly, these dichotomous variables are highly correlated suggesting a high presence of multi-lateral cooperation linkages simultaneously involving different types of actors. Such a high level of correlation justifies the application of the PCA.

Table A1.1: Principal component analysis for patterns of cooperation – Italy CIS 2012

	Eigenvalue	Explained variance	Cumulative	Scoring coefficients		
					Comp1	Comp2
First component	4.05	0.58	0.58	Cooperation within group	0.6	-0.1
Second component	0.68	0.10	0.67	Cooperation with suppliers	0.5	0.0
Third component	0.60	0.09	0.76	Cooperation with customers	0.2	0.3
Fourth component	0.54	0.08	0.84	Cooperation with competitors	0.5	-0.1
Fifth component	0.49	0.07	0.91	Cooperation with consultants	0.3	0.3
Sixth component	0.35	0.05	0.96	Cooperation with universities	-0.1	0.6
Seventh component	0.29	0.04	1.00	Cooperation with government/ public research institutes	-0.2	0.7

Rotation method: Oblimin with Kaiser normalization.
Observations: 5,137 (firms with PP contracts).

Table A1.2: Principal component analysis for patterns of cooperation – Norway CIS 2014

	Eigenvalue	Explained variance	Cumulative	Scoring coefficients		
					Comp1	Comp2
First component	4.27	0.61	0.61	Cooperation within group	0.5	-0.1
Second component	0.73	0.10	0.71	Cooperation with suppliers	0.5	-0.1
Third component	0.58	0.08	0.80	Cooperation with customers	0.4	0.1
Fourth component	0.43	0.06	0.86	Cooperation with competitors	0.5	-0.1
Fifth component	0.37	0.05	0.91	Cooperation with consultants	0.4	0.1
Sixth component	0.33	0.05	0.96	Cooperation with universities	0.0	0.6
Seventh component	0.28	0.04	1.00	Cooperation with government/ public research institutes	0.0	0.7

Rotation method: Oblimin with Kaiser normalization.
Observations: 1,691 (firms with PP contracts).

This method allows reducing the number of variables while keeping a relevant part of the original information. Therefore, the original variables detecting seven different patterns of cooperation have been processed with PCA and subsequently replaced by two synthetic measures of cooperation obtained by retaining the first two components, which together account for around 70% of the explained variance (though only the first component actually shows an eigenvalue well above one). Looking at the patterns arising after oblique rotation (the usual method to better separate the extracted components), we can see that, in both countries, three variables (cooperation within group, with suppliers and competitors) load on component 1 with factor loadings exceeding 0.5; instead, only two variables load on component 2 (cooperation with universities and cooperation with government or public research institutes). Accordingly, we have employed this latter component as a specific indicator of firms' cooperation with universities and public research institutes, while considering the first one as proxy of cooperation with other external actors.

Table A1.3: Principal component analysis for innovative activities – Italy CIS 2012

	Eigenvalue	Explained variance	Cumulative	Scoring coefficients		
					Comp1	Comp2
First component	3.26	0.47	0.47	R&D intra-muros	-0.1	0.7
Second component	0.85	0.12	0.59	Acquisition of machinery	0.6	-0.2
Third component	0.73	0.10	0.69	Acquisition of external knowledge	0.3	0.1
Fourth component	0.68	0.10	0.79	Training for innovative activities	0.6	-0.1
Fifth component	0.58	0.08	0.87	Marketing activities for the introduction of innovations	0.4	0.1
Sixth component	0.51	0.07	0.94	Product design activities	0.0	0.6
Seventh component	0.40	0.06	1.00	Other innovative activities	0.2	0.3

Rotation method: Oblimin with Kaiser normalization.
Observations: 5,137 (firms with PP contracts).

Table A1.4: Principal component analysis for innovative activities – Norway CIS 2014

	Eigenvalue	Explained variance	Cumulative	Scoring coefficients		
					Comp1	Comp2
First component	4.20	0.60	0.60	R&D intra-muros	0.3	0.2
Second component	0.68	0.10	0.70	Acquisition of machinery	0.0	0.5
Third component	0.55	0.08	0.77	Acquisition of external knowledge	-0.3	0.7
Fourth component	0.49	0.07	0.85	Training for innovative activities	0.1	0.4
Fifth component	0.40	0.06	0.90	Marketing activities for the introduction of innovations	0.6	-0.1
Sixth component	0.37	0.05	0.96	Product design activities	0.6	-0.1
Seventh component	0.31	0.04	1.00	Other innovative activities	0.4	0.1

Rotation method: Oblimin with Kaiser normalization.
Observations: 1,691 (firms with PP contracts).

Tables A1.3 and A1.4 report the results of PCA for firms' engagement in different types of innovative activities in Italy and Norway. For Italy the first component includes mainly the acquisition of machinery and training for innovative activities, and thus has been employed as proxy of innovative activities mainly devoted to process innovations; the second component is mainly associated with R&D intra-muros and product design activities, and therefore has been employed as indicator of innovation activities mainly devoted to product innovations. Likewise, in the case of Norway, the first component, employed as proxy of innovative activities devoted to product innovations, is mainly associated with marketing and product design activities; the second, used as indicator of innovative activities dedicated to process innovations, accounts for the acquisition of external knowledge and machinery.

Appendix 3 - Two-steps estimations (robustness checks)

Table A2.1: Heckman probit model with sample selection: two-steps estimation

	ITALY (CIS 2012)		NORWAY (CIS 2014)	
	PPfI (outcome eq.)	PP (selection eq.)	PPfI (outcome eq.)	PP (selection eq.)
Cooperation with universities and public research institutes	-0.0472*		0.1233***	
	(0.0245)		(0.0389)	
Cooperation with other external actors (suppliers, competitors, etc.)	0.0380***		0.0594***	
	(0.0119)		(0.0203)	
Innovative activities mainly devoted to process innovation°	0.2077***		-0.0032	
	(0.0145)		(0.0395)	
Innovative activites mainly devoted to product innovation°°	-0.0200		0.2246***	
	(0.0245)		(0.0232)	
Human capital (ordinal, values 0 to 6)	0.0315**		0.0310	
	(0.0157)		(0.0326)	
High-tech manufacturing industries	0.2548*	-0.4020***	0.1149	-0.1771**
	(0.1382)	(0.0529)	(0.1749)	(0.0778)
Low-tech manufacturing industries	0.4110***	-0.5267***	0.1795	-0.3436***
	(0.1286)	(0.0407)	(0.1881)	(0.0576)
Knowledge intensive business services	0.0506	-0.0353	-0.0527	0.3050***
	(0.0873)	(0.0388)	(0.1526)	(0.0546)
Trade	0.0831	-0.2690***	-0.3608**	0.3666***
	(0.0864)	(0.0342)	(0.1795)	(0.0732)
Construction	-0.7985***	0.4779***	-0.2693	0.5540***
	(0.0900)	(0.0346)	(0.2109)	(0.0713)
Small firms	0.3086***	-0.2489***	0.3657*	-0.4671***
	(0.0877)	(0.0382)	(0.1938)	(0.0689)
Medium-sized firms	0.2423***	-0.1167***	0.1081	-0.2330***
	(0.0854)	(0.0394)	(0.1397)	(0.0686)
Firms belonging to a group		0.0696***		-0.0145
		(0.0237)		(0.0475)
Firms operating in domestic market only		0.0504**		-0.0289
		(0.0244)		(0.0409)
New ways of organising external relations		0.4501***		0.2947***
		(0.0271)		(0.0561)
Constant	0.6586***	-0.4898***	-0.0381	-0.1737**
	(0.1881)	(0.0494)	(0.4570)	(0.0882)
Inverse Mills Ratio	-1.6864***		-0.9950**	
	(0.1665)		(0.4743)	
Observations	5,137	18,697	1,691	4,974
Log pseudolikelihood	-1,831.63	-10,215.04	-793.32	-3,012.07

Robust standard errors in brackets. Large size and Other services, among firm size and industry dummies, used as reference category. *** p<0.01, ** p<0.05, * p<0.10. °=Acquisition of machinery; acquisition of external knowledge; training for innovative activities. °°=Product design activities; marketing activities for the introduction of innovation; R&D intra-muros.

Table A2.2: Heckman probit model with sample selection: two-steps estimation (SMEs only)

	ITALY (CIS 2012)		NORWAY (CIS 2014)	
	PPfI (outcome eq.)	PP (selection eq.)	PPfI (outcome eq.)	PP (selection eq.)
Cooperation with universities and public research institutes	-0.0257		0.0841**	
	(0.0336)		(0.0419)	
Cooperation with other external actors (suppliers, competitors, etc.)	0.0530***		0.0749***	
	(0.0166)		(0.0220)	
Innovative activities mainly devoted to process innovation°	0.2442***		-0.0113	
	(0.0168)		(0.0420)	
Innovative activites mainly devoted to product innovation°°	-0.0272		0.2126***	
	(0.0276)		(0.0248)	
Human capital (ordinal, values 0 to 6)	0.0284*		0.0431	
	(0.0172)		(0.0346)	
High-tech manufacturing industries	0.2302	-0.4040***	0.0930	-0.1045
	(0.1806)	(0.0631)	(0.1745)	(0.0811)
Low-tech manufacturing industries	0.4098***	-0.5106***	0.1011	-0.3224***
	(0.1429)	(0.0438)	(0.1929)	(0.0609)
Knowledge intensive business services	0.0349	-0.0472	-0.1333	0.3157***
	(0.0996)	(0.0421)	(0.1627)	(0.0572)
Trade	0.0521	-0.2593***	-0.3597*	0.3372***
	(0.0959)	(0.0363)	(0.1864)	(0.0773)
Construction	-0.7907***	0.4811***	-0.2543	0.5545***
	(0.1007)	(0.0363)	(0.2250)	(0.0751)
Small firms	0.0902	-0.1364***	0.2690**	-0.2327***
	(0.0653)	(0.0279)	(0.1109)	(0.0408)
Firms belonging to a group		0.0673***		-0.0162
		(0.0242)		(0.0481)
Firms operating in domestic market only		0.0537**		-0.0237
		(0.0257)		(0.0428)
New ways of organising external relations		0.4326***		0.3098***
		(0.0296)		(0.0601)
Constant	0.8656***	-0.6059***	0.0580	-0.4224***
	(0.2261)	(0.0431)	(0.5385)	(0.0697)
Inverse Mills Ratio	-1.6654***		-0.9946**	
	(0.1930)		(0.4857)	
Observations	4,569	16,882	1,496	4,552
Log pseudolikelihood	-1,497.99	-9,161.58	-699.32	-2,741.56

Robust standard errors in brackets. Medium-sized firms and Other services, among firm size and industry dummies, used as reference category. *** p<0.01, ** p<0.05, * p<0.10. °=Acquisition of machinery; acquisition of external knowledge; training for innovative activities. °°=Product design activities; marketing activities for the introduction of innovation; R&D intra-muros.