Economics of Innovation and New Technology

ISSN: 1043-8599 (Print) 1476-8364 (Online) Journal homepage: https://www.tandfonline.com/loi/gein20

Pre-commercial procurement, procurement of innovative solutions and innovation partnerships in the EU: rationale and strategy

Elisabetta Iossa, Federico Biagi & Paola Valbonesi

ECONOMICS OF INNOVATION AND NEW TECHNOLOGY, 2018
VOL. 27, NO. 8, 730–749
https://doi.org/10.1080/10438599.2017.1402431

Routledge
Taylor & Francis Group

Check for updates

Pre-commercial procurement, procurement of innovative solutions and innovation partnerships in the EU: rationale and strategy

Elisabetta Iossa [a,b,c*], Federico Biagi [d,e†] and Paola Valbonesi [b,e,f]

[a]Department of Economics and Finance, University of Rome Tor Vergata, Rome, Italy; [b]IEFE-Bocconi, Milan, Italy; [c]Center of Research in Procurement and Supply Chain, University of Rome Tor Vergata, Rome, Italy; [d]European Commission, Joint Research Centre, Directorate Growth and Innovation, Human Capital and Employment Unit, Sevilla, Spain; [e]Department of Economics and Management, University of Padua, Padua, Italy; [f]Higher School of Economics, National Research University, Moscow, Russia

ABSTRACT
We discuss public procurement instruments for acquiring innovation, focusing on the European Pre-commercial Procurement, Procurement of Innovative Solutions and Innovation Partnerships. We analyse, in particular, how firms' innovation incentives are affected by: (i) economies of scope and externalities between R&D and large-scale production; (ii) the degree of specificity of the innovation; (iii) the presence of Small and Medium Enterprises in the market and the level of market competition; (iv) the risk of market foreclosure and supplier lock-in. Our study contributes to the literature on incentives in demand-side innovation policy by tapping into the contractual design features and by offering relevant implications for academics and policy-makers.

KEYWORDS
Innovation; demand-side policies; incentives; pre-commercial procurement; public procurement of innovative solutions; innovation partnership; bundling; rationales

JEL CLASSIFICATION
O31; O32; O38; H57

1. Introduction

Public procurement accounts for a substantial share of world trade flows, amounting to €1000 billion per year and 10–25% of the world gross domestic product (GDP); in the EU, it is estimated that the public purchase of goods and services (including innovative ones) accounts for 16% of GDP.[1]

By using this large purchasing power to procure and encourage innovation and its diffusion, governments can stimulate innovation and boost competitiveness and growth (Cabral et al. 2006).[2] Furthermore, procuring innovative solutions can help improve the efficiency of public services in sectors such as education, energy, e-health, ICT and transport (Aho 2006).

Among the public procurement instruments for acquiring Research and Development (R&D) services or innovative solutions, special attention is currently being devoted in Europe to Pre-commercial Procurement (PCP), Public Procurement of Innovative Solutions (PPI) and Innovation Partnerships (IP). The aim of this paper is to discuss the comparative strengths and weaknesses of alternative mechanisms for procuring innovation, focusing on the impact of bundling R&D and production/commercialisation and building on the economic theory of incentives.

We note that procurement contracts are characterised by an inherent asymmetry of information between the procurer (the Principal) and the firm (the Agent) performing the tasks, since efforts are

CONTACT Elisabetta Iossa elisabetta.iossa@uniroma2.it Department of Economics and Finance, University of Rome Tor Vergata, Via Columbia 2, Rome 00133, Italy
*www.proxenter.it
†The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.

difficult to observe and verify. Coupled with the innovation uncertainties, this makes it crucial to design contracts and procurement instruments that provide the firm with inherently correct incentives to meet the procurement objectives. Building on the economic literature of incentives (see Laffont and Martimort 2002), we argue that the key difference between IP, on the one hand, and PCP and PPI, on the other hand, is that the former is characterised by the *bundling* of two stages of the innovation process, the R&D stage and the large-scale production/commercialisation stage, and that this bundling has dramatic effects on the incentives of firms to undertake the required tasks at desirable standards.

By focusing on PCP, PPI and IP, we contribute to the debate on how public procurement can be an effective way of improving the efficiency of public services and stimulating innovation and competitiveness in key sectors and priorities, provided that the right competencies and incentives exist within the public sector. We discuss the factors that result in 'procurement failure' and their implications for public procurement as an innovation policy.

Our paper also contributes to the substantial body of literature on government support schemes for innovation (see Aschhoff and Sofka 2009, for an informal discussion of alternative policy instruments; see also Edquist et al. 2015; Edquist and Zabala-Iturriagagoitia 2012; Lember, Kattel, and Kalvet 2014; Uyarra 2016) by adding a focus on the novel IP introduced by the Procurement Directive 2014/24/EU.

In particular, we point out that the use of contract rights to reward highly valuable innovation may help exploit economies of scope, boost incentives for research effort, reduce commercial risk and ease access to finance. However, it may also create dominant positions in the market, favour lock-in situations at the expense of entrants and Small and Medium Enterprises (SMEs), and increase the risk of undue continuation of low-value projects. We thus argue that whether or not it is optimal to bundle the two stages of the innovation process (the R&D stage and the large-scale production/commercialisation stage) depends on the following factors:

- the presence of economies of scope, and/or positive technical or knowledge externalities between R&D and large-scale production;
- the degree of specificity of the innovation to the needs of the public procurer, and thus whether it is expected that there will be a significant demand for the innovative solution beyond that of the public procurer;
- the role of SMEs in the market;
- the level of potential market competition, the risk of market foreclosure and the need to overcome supplier lock-in;
- whether it is possible for procurers to set clear performance targets on the required solutions, making the value of the innovation easy to observe and verify ex post;
- the competency and efficiency of the procurer's organisation.

The paper is organised as follows. In Section 2, we briefly present and discuss factors leading to market failures that provide a rationale for demand- and supply-side innovation policies, and for the use of public procurement of innovation. In Section 3, we describe alternative instruments for procuring R&D and innovation, focusing on PCP, PPI and IP. In Section 4, we compare these instruments in the light of the economic theory of contracts and incentives, focusing on the benefit and costs of bundling the R&D phase with the production phase. In Section 5, we draw attention to those factors that may cause procurement failure. In Section 6, we present our conclusions.

2. Demand- and supply-side innovation policies to address market failure

A number of factors lead to an inefficient level of investment in R&D-based innovation and innovation processes, leaving demand unsatisfied and causing technological lock-in (for a survey on market failure in innovation, see Martin and Scott 2000). Some of these factors mainly refer to the supply side of the market, others largely belong to the demand side, and others are due to the intrinsic characteristics of the innovation process. Given our focus on procurement-related policies, our aim here is not to provide an exhaustive discussion of demand and supply market and system failures. We simply present in the three columns demand-side factors, supply-side factors and innovation characteristics that cause market failures. Notice that in real settings, some of such factors and characteristics could be interconnected and mutually reinforcing.

Asymmetric information issues characterise R&D activities, making it difficult to verify R&D effort or motivate researchers, see (1) in Table 1, and to raise funds to finance the investment – see (2) in Table 1. Risk aversion deters firms from investing in innovation projects – particularly SMEs, which have limited possibilities of diversifying their investments.

Innovations also have specific characteristics that may prevent firms from investing adequately. In particular, firms may not have the capacity for innovation – they may lack the human capital and physical capital necessary to undertake investment because of inefficiencies within their organisations or due to capital and labour market imperfections, see (3) in Table 1.

Information about potential demand for innovative products/services may be dispersed and it may not reach potential suppliers. Potential private and public users may have information about their preferences and needs that they fail to communicate to the market because of communication costs or lack of incentives within organisations, see (4) and (5) in Table 1 (see Von Hippel 2005 for an in-depth discussion on the role of users in directing the innovation process). Public administrations with similar needs but located in different geographical areas or different countries may also fail to pool their demands and express them to the market, due to communication costs and coordination failures, see (6) in Table 1.[3] Furthermore, knowledge is a public good with elements of non-rivalry and non-excludability, see (7) in Table 1, making suppliers unable to fully appropriate the whole private and social benefits of their investment, even when the intellectual property rights (IPRs) on the resulting innovations can be relatively well defined, see (8) in Table 1.[4]

Network externalities – occurring when the value of a network to users is positively correlated with the size of the network – represent a further factor that may impede efficient investment and the uptake of valuable innovations. The uptake of innovative products and the transition to new technologies may be difficult to achieve where there are lock-in costs. Once a network is established, it may be too costly for users to switch to a new technology, even if it is of superior quality, see (9) in Table 1.

Traditionally, supply-side policies have been the main instrument governments in Europe have relied upon in order to develop innovative markets and revive traditional segments. Supply-side policies are defined by the OECD (2014) as policies that strengthen the ability or the capacity of the economy to generate knowledge and produce innovation, by boosting public investment in R&D,

Table 1. Main factors that cause market failure.

Supply-side factors	Demand-side factors	Innovation characteristics
(1) Difficulty to verify R&D effort, making it difficult to incentivise it within organisation and across organisations	**(4) Unexpressed private demand** for innovation, due to lack of knowledge from potential buyers on the potential supply of innovation or due to the cost of acquiring and processing information by dispersed users	**(7) Difficulty to verify the value of innovation** and make it contractible (i.e. it can be described in a contract and verified by a Court of Law) creating inefficiencies in the purchase or R&D effort and its financing
(2) Capital market imperfections (due e.g. to informational asymmetries) make it difficult for innovators to find external financing and to diversity risk	**(5) Unexpressed public demand for innovation** due to lack of incentives in public administrations to express a demand for innovative solutions	**(8) Limited appropriability** of the benefit from the innovation, because knowledge is a public good with elements of non-rivalry and non-excludability
(3) Little innovation capacity because of lack of human and physical capital due to inefficiencies within organisations	**(6) Coordination failure** between demand sources (e.g. public authorities of different countries), which does not allow to internalise network externalities	**(9) Network externalities** creating lock-in effects, thus weakening incentives to switch to new valuable technologies

Source: our elaborations.

and the formation of human capital and private R&D. Examples of supply-side policies are: subsidies to private R&D (such as R&D grants or loans), tax credits to R&D, publicly sponsored R&D, enhanced capacities for knowledge exchange and support for education and training. Policies that support or ease knowledge transfer are also supply-side policies (Edler 2007).

An alternative, and in many respects complementary, approach is provided by demand-side policies. These are at the centre of the current innovation policy in Europe (see Kok 2004 and Aho 2006; Aschhoff and Sofka 2009) and are used world-wide (see OECD 2011, 2014 for a review of different countries' approaches; see also the extensive management literature including Edler 2007, 2013, 2016; Edler and Georghiou 2007; Edquist and Hommen 1999; Edquist et al. 2015; Edquist and Zabala-Iturriagagoitia 2012; Uyarra 2016; and Lember, Kattel, and Kalvet 2014 for thoughtful discussions). As highlighted by the OECD (2011), the idea of fostering innovation through demand-side policies is not new in sectors such as defence, energy and transport. The renewed interest may be understood if one considers the new societal challenges of ageing and the environment. Disappointment with the outcomes of traditional supply-side measures may also have played a role.

The rationale for demand-side innovation policies is that suitable innovations may fail to materialise because there may be a problem on the demand side. Even firms that have sufficient innovation capacity may have insufficient incentives to invest because the potential demand for innovation is unknown, uncertain and fragmented, or because users are locked into existing technologies (see Table 1). In these cases, demand-side innovation policies can help boost innovation and its diffusion by helping to identify the demand for innovation and improve the conditions for the innovation (Edler 2007, 2013).

As extensively discussed in the management literature on procuring innovation, there are many ways of achieving this; for example, by:

- facilitating the identification and transmission of users' needs;
- encouraging user coordination (e.g. through joint or collaborative procurement of R&D services);
- increasing the demand for innovation, incentivising public buyers to purchase innovations via procurement of R&D or of innovative solutions or through technology mandates and standard settings that define new functional requirements for products and services that can be met only by developing new solutions;
- catalysing policies, which involve the public sector buying the innovative good from the private sector, coordinating users and, with a systemic approach, taking into account interdependences and feedbacks;
- increasing demand to overcome lock-in effects due to network externalities.

Demand-side policies include:

(i) innovation-oriented public procurement (i.e. the purchase of innovative solutions and/or of R&D services by the public authorities);
(ii) innovation-oriented regulations, such as labelling and certification, recycling regulations, emission standards, which set performance levels as regards quality, compatibility requirements for allowed technologies or health, safety, environmental outcomes of products or services);
(iii) innovation-oriented standards (i.e. standards ensuring, for example, interoperability, minimum safety and quality).

In our view, demand-side and supply-side innovation policies address the different barriers on the two sides of the market and they should be viewed as complementary policy instruments. On the one hand, the effectiveness of supply-side policies (e.g. research grants) rests on the firms' ability to pin down a demand for their innovation. On the other hand, the effectiveness of a demand-side policy (e.g. actions for joint procurement of innovation) rests on the firms' capacity to meet the demand requirements. As the OECD (2014, 11) puts it 'Neither supply-side nor demand-side policies are likely to be optimally effective in isolation. Efforts to foster innovation will likely have the greatest effect when they address the entire innovation chain.' As an example, consider the case of market failure due to capital market imperfections. A supply-side policy intervention that aims to facilitate access to financial sources will certainly help SMEs' innovation. However, provision of funds without market opportunities for SMEs will still be ineffective. Facilitating access to funding by SMEs could become more effective if it goes together with innovation-oriented procurement instruments designed to induce SME participation (like PCP – see below). PCP will help to create market opportunities for SMEs, by easing access to the demand for innovation coming from the public sector.

3. Innovation-related public procurement: background

Innovation-oriented procurement strategies occur when a public agency purchases, or places an order for a product – service, good or system – that does not yet exist, but which could probably be developed within a reasonable period of time as a result of additional or new innovative work by the organisation(s) willing to produce, supply and sell the products being purchased (Edquist, Hommen, and Tsipouri 2000; Edquist et al. 2015).

As a demand-side policy tool, public procurement can play an important role in tackling market failures. First, by procuring R&D or innovative goods and services, public authorities in charge of providing public services can clearly express their needs to the market. This helps to overcome asymmetric information problems with the supply side and to ensure the delivery of higher quality and more cost-effective public services (OECD 2011). Second, financial support to joint procurement may stimulate communication among procurers and overcome coordination problems among public authorities. Procurement of new technologies may also help to catalyse the demand for innovation and meet unsatisfied private needs. This, in turn, can reduce lock-in effects due to network externalities, by creating a sufficiently large demand for the new technology. Third, a clear demand from the public sector may also incentivise investment in innovation by firms, including SMEs, by reducing the commercial risk of their R&D and innovation investment and helping them to gain access to funds. This would enhance the innovative performance of national industries, increasing their productivity, competitiveness and, ultimately, growth.

The potential of innovative public procurement has been emphasised in a number of European Commission reports (European Commission 2005, 2007). Based on these reports, the European Commission is now calling on the European Union Member States to set aside dedicated budgets for PCP and Public Procurement of Innovative products and services (PPI), and has devoted specific resources for procurement of innovation in the EU Framework Programme for Research and Innovation ('Horizon 2020'). Finally, the new European Directives on public procurement 2014/24 and 2014/25 have modernised the legislative framework on public procurement, making the rules more flexible in order to foster demand for innovative goods and services.

In what follows, we focus on the instruments that are at the centre of the European policy on PCP (3.1) and PPI (3.2), presenting their main characteristics in detail. In Section 3.3, we then present Innovation Partnership (IP), a special procedure for the establishment of a long-term partnership for innovation.

3.1. Pre-commercial Procurement

PCP is a relatively new approach to procuring R&D services that does not constitute state aid. The approach is defined in European Commission (2007), and discussed in detail by Bos and Corvers (2006), Rigby (2016) and Edquist and Zabala-Iturriagagoitia (2015).[5]

Under a PCP scheme, having identified a specific procurement need that existing solutions cannot readily satisfy, the public procurement authority procures R&D services. Multiple private firms compete to carry out an exploratory phase and propose suitable solutions, up to prototype building and the production of a limited number of units to test the characteristics and properties of proposed solutions.

In particular, the main features of PCP are the following:

Unbundling of R&D and Production: There is a separation (unbundling) between (i) the procurement of R&D services (PCP phase) and (ii) the (possible) purchase of commercial volumes of end products (from large-scale production) resulting from the R&D phase. The R&D covers up to 'original development' of a first product or service; it may include limited production or supply in order to incorporate the results of field testing and to demonstrate that the product or service is suitable for production, but it does not extend to quantity production. The latter is part of the commercial development and related activities such as integration, customisation, incremental adaptations and improvements to existing products or processes. This means that a company that has undertaken R&D services and developed a working solution has no guarantee that it will also win a follow-up contract for the large-scale production of the proposed solution.

Benefits sharing: In PCPs, the benefits are shared between the procurer and the contractor(s). The public procurer is not the only beneficiary of the developed solution. Unlike traditional R&D procurement, under PCPs the public procurer does not obtain exclusive rights to the R&D results and the benefits from the resulting innovations are shared between the public sector and the firm which has developed the solution. In practice, this means that IPRs are either: (i) fully assigned to the private PCP contractor, with the public procurer keeping a free license of exploitation for internal use and the firm being required to grant non-exclusive rights to third parties under market conditions, or (ii) shared between the public and private parties, i.e. through sharing of the rights to commercial exploitation.

Competitive development in stages: The public procurer buys R&D services from several suppliers in parallel. These suppliers have alternative proposals/solutions and compete on economic and technical grounds. The procurement process is divided into multiple sequential phases, which include solution design, prototype development and testing of first products, as shown in Figure 1.

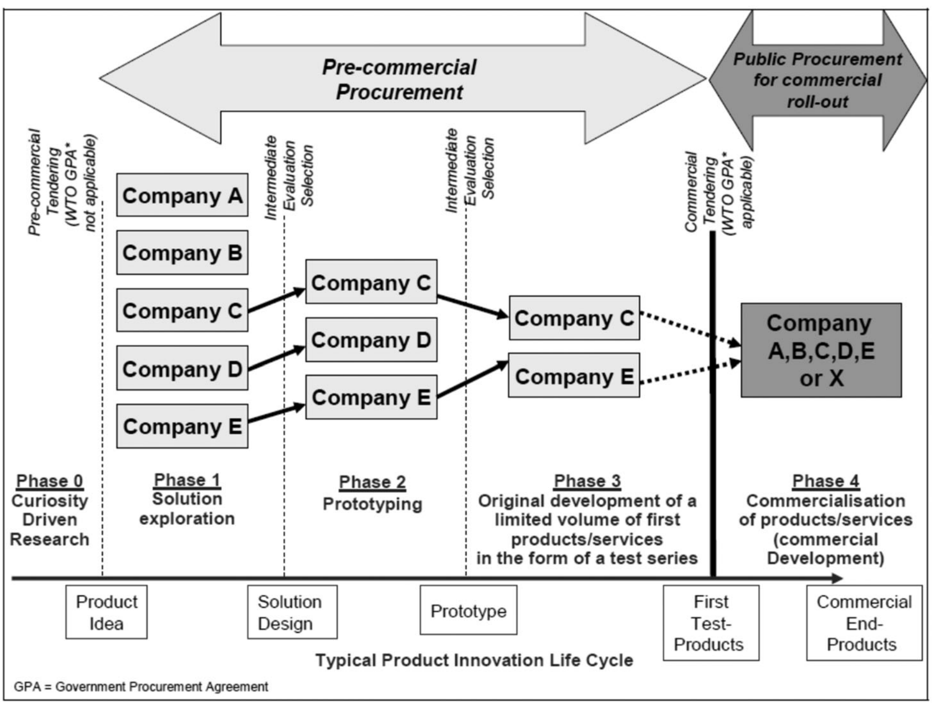

Figure 1. Unbundling under pre-commercial procurement (source: EC 2007, 4).

After each stage, the procurer compares offers using the Most Economically Advantageous Tender (MEAT) criterion, and decides which solution can proceed to the subsequent stage. The MEAT criterion provides for procurers to assess tenders considering both the economic offer and the technical/quality dimension of the offer.

Risk sharing: Not only benefits but also risks are shared between the private contractors and the public procurement authority. In each stage, the firms compete, bidding on the financial contribution requested to the procurer in order to undertake the R&D services (this constitutes one of the elements upon which are evaluated). This contribution helps them cover the cost of R&D for the exploration phase and the costs related to prototyping and testing. The contribution could include different monetary thresholds for each stage, where the threshold may be set to combine the need to share risk, and thus induce firm participation, with the need to provide incentives for the innovator to reach subsequent stages by back-loading payments.

The monetary value of the firms' IPR rights induces bids that, internalising this value, are below the level that would arise under exclusive development: the greater the monetary value of the IPRs attributed to the firm, the lower the contribution requested from the procurer. This contribution can be either above or below the development costs, depending on the degree of competition in the PCP process and on the value of the IPRs. Should the project not succeed, both the public party and the private party face a loss. In this respect, there is risk sharing between the two parties.

Multiple sourcing: There is multiple sourcing in the sense that multiple firms are allowed to compete in parallel during all stages of the PCP. Ideally, at least two firms should reach the final stage, when they develop their prototypes and test a set of first products, so as to maintain competitive pressure until the end of the process. This is specific to PCP, and highlights how it differs from traditional R&D procurement where single sourcing is typical.

PCP cases: In the ICT sector, we can find recent examples of PCP. Cloud for Europe uses PCP to identify innovative solutions for cloud services that best fit public sector needs, and provides high-quality information to public procurers about the potential of cloud services.[6] Another example is the 'Distributed European Community Individual Patient Healthcare Electronic Record' (DECIPHER). This was one of the responses to European procurement authorities' requests for solution exploration, prototyping and original development of interoperable mobile solutions that would enable secure cross-border access to existing patient healthcare portals and efficient and safe medical care of mobile patients in EU Member States. These solutions will be of special interest in the management of patients with chronic diseases or unplanned care episodes (for a discussion of this case, see Bedin, Decarolis, and Iossa 2015).

The ITS (Innovative Transport System) Innovation Stockholm Kista is a catalytic PCP which was launched in 2012 by the City of Stockholm, the Swedish Transport Administration, Stockholm Public Transport and Kista Science. It aims to stimulate the development of new solutions for a more efficient use of transport infrastructure. The initial application is for transport to and from the city of Kista, but the long-term objective is to develop solutions to serve citizens of the wider Stockholm region.[7] The proposed solutions are scalable and equipped with appropriate business models so that they can serve citizens in the wider Stockholm region after competition closure.

A very recent example of PCP in Europe is the German THALEA project, launched in March 2015.[8] The aim of THALEA is to create a telemedical control-centre software for tele-ICUs which can capture workflow-data, physiological parameters, laboratory results and current medication in order to set up a robust real-time analysis tool. This will enable telemedical ICU-staff to monitor and oversee an entire ICU patient population.

3.2. Public Procurement of Innovative Solutions (PPI)

Horizon 2020, the new EU Framework Programme for Research and Innovation, includes a legal definition of Public Procurement of Innovative solutions (PPI), which is a useful basis for deciding the eligibility of procurement actions for EU financing. PPI is defined as procurement where the contracting authority acts as a launch customer, an early adopter, for innovative goods or services that are not yet available on a large-scale commercial basis (it may also include conformance testing). PPI does not include the procurement of R&D services, as does PCP discussed above.[9] The European focus on PPI and its funding policy reflects the view that PPI could be an instrument to achieve Europe 2020 wider economic, environmental and societal objectives, in areas such as mobility, health, construction, e-government, waste management and recycling, where the public sector accounts for a big part of demand and can use procurement as a means to address key societal challenges such as sustainable transport, resource-efficiency or healthy ageing.

Some authors (see e.g. Edquist and Zabala-Iturriagagoitia, 2012) propose that a distinction should be made between two different types of PPI, depending on the degree of innovativeness of the innovation process: Adaptive PPI and Developmental PPI.

Adaptive PPI: This occurs when the procured product or system is only new to the country (or region) of procurement. Innovation is thus required in order to adapt an existing product/system to specific (national, local) conditions. It may also be labelled 'diffusion-oriented' or 'absorption-oriented' PPI. It implies *incremental innovation*.

Developmental PPI: This occurs with the creation of new-to-the-world products and/or systems through the procurement process. It may be regarded as 'creation-oriented' PPI and involves *radical innovation*.

The main characteristics of PPI can be summarised as follows:

Early adoption: Under PPI, the procurer acts as a launch customer and early adopter. Thus, the procurer is a first buyer for an innovative solution not yet available on a large scale.

Unbundling of R&D and large-scale production: PCP and PPI are separate but complementary instruments: following a successful PCP that has led to the development of a suitable prototype, the procurer may decide to procure the production of the solution on a large scale (PPI).[10] It should be remembered, however, that the unbundling that characterises the PCP process ensures that the awardees of the PCP have no special rights in the PPI phase. This separation between PCP and PPI allows companies that have developed products through means other than PCP (e.g. through R&D grants, own funding, venture capital) to participate in the PPI procurement on an equal footing with the PCP solution developer. PPI initiatives do not necessarily have to include a PCP scheme, as they can be run independently. In this case, the innovative phase is part of the PPI.

PPI is not a specific procurement procedure. Typically, it uses either a negotiated competitive procedure or a competitive dialogue. In the new European Directive on Public Procurement 2014/24/EU, which came into force on 17 April 2014, Art 26 states that Member States shall provide that contracting authorities may apply a competitive procedure with negotiation or a competitive dialogue with regard to works, supplies or services including design or innovative solutions. The competitive procedure with negotiation is laid down in Art. 29; and the Competitive Dialogue in Art. 30. These procedures are characterised by a negotiation or dialogue phase, which gives public procurers the flexibility they need to be able to acquire the innovation-oriented goods, products or service they require. See the directives for more details.

PPI cases: Consip, the Italian central procurement agency, provides an example of PPI. This agency was assigned the task of organising, implementing and monitoring the procurement of heating services for the Italian public administration. It did this by implementing in a large number of administrations a performance-based contract, which achieved cost efficiency. By introducing performance standards, the contract helped to encourage innovation in the supplier's solutions.

More generally, the European Commission has set up a platform for innovation providing information on PPI projects. In the food industry, INNOCAT encourages eco-innovation in the catering industry through a series of tenders published by public and private buyers across Europe. In the Health industry, the HAPPI project brings European health providers together to find and jointly procure innovative and sustainable solutions for healthcare for the elderly. The aim is to help hospitals with limited budgets find products that cater for the specific needs of elderly patients. In the construction industry, the Innobuild project's partners Falu (Sweden) and Layngdal (Norway) are currently working on a joint procurement strategy for sustainable high-tech building projects for senior citizens.[11]

3.3. Innovation Partnerships

Art 31 of the new European Commission Directive 2014/24/EU on Public Procurement introduced the Innovation Partnership (IP) as a new special procedure for the establishment of a long-term partnership for the development and subsequent purchase of new, innovative products, works and services, provided they can be delivered at agreed performance levels and costs. This procedure enables public procurers to have an innovative solution developed and tailored to their specific needs.

The main characteristics of IPs are as follows:

Bundling of R&D and large-scale production: the IP foresees the funding of R&D for an innovative solution in the same procedure as the procurement of the solution production. Thus, the R&D stage and the production/commercialisation stage are all bundled under the same procurement instrument, rather than being kept separate as they would be in PCP and PPI procurement.

Competitive development in phases: operators participating in the procedure submit research and innovation projects designed to meet the needs identified by the procurement authority. The procedure has several stages, including an R&D stage up to prototype and testing, and a subsequent production stage, namely the manufacturing of the supply or the provision of the services.

Solutions proposed by bidders are compared at each stage on economic and technical grounds, using the MEAT criterion. Based on the set criteria and targets, the contracting authority may decide to restrict the number of participants or even to terminate the partnership and launch a new procurement procedure for the remaining phases, provided that it has acquired the relevant IPRs. The contract is awarded in accordance with the rules for a competitive procedure with negotiation (Article 27 of European Commission Directive 2014/24/EU on Public Procurement), which allow procurement authorities to negotiate the tenders submitted in order to improve the content of the offers so that they correspond better to the award criteria and minimum requirements.

Negotiation on partnership structure: there are no set rules on how costs and benefits should be shared or how IPR should be allocated. The only requirement is that, in the procurement documents, the procurer defines the arrangements applicable to IPRs. Negotiation between the public and private party can take place during the procurement process up until the final stage, provided that no confidential information is revealed to third parties and that the negotiations take place with all participants simultaneously.

Single or multiple sourcing: the procurement authority may decide to set up the partnership with one partner or with several partners, which conduct separate research and development activities.

Limit on the estimated value of supplies: if the process reaches the final stage of large-scale production, there is a limit on the estimated value of supplies (i.e. the volume of products that is bought under the partnership), which needs to be 'not disproportionate to the R&D investment'. There are no set guidelines, but the idea is that the innovation partnership should be structured in such a way that it provides the necessary 'market-pull', without creating a long-term partnership that may foreclose the market.

IP cases: In the US, the Total Package Procurement Concept (TPPC) was first used for C-5A procurement in the Air Force.[12] This system required contractors to bid, in their original proposals, for the entire development and production of an aircraft or missile. The contract was awarded after a technical and price competition and it was negotiated by the government and Lockheed, at a time when the administration sought to fight a guns-and-butter war in Vietnam. A later TPPC contract was negotiated for the F-14 airplane.

IP-like procurement has been implemented in Europe as well. An example is the tender for the online energy-efficient products facility launched in 2013 by the Executive Agency for Competitiveness and Innovation.[13] The main tasks of the service contract consist of developing, managing and promoting a multilingual and multi-disciplinary electronic facility on eco-design and energy labelling to support the implementation of the Eco-design and Energy Labelling Directives. [14] In 2016, this model was announced by Transport for London for the development of a new composite conductor rail system to fit constrained areas of the underground network and to improve the energy efficiency.[15]

4. Procurement of innovation: choosing between instruments

Having established that public procurement can help address market failures in innovation, we now compare incentives under the procurement instruments discussed in the previous section. One of the key distinctions between these procurement instruments is the degree of bundling of the different stages of the innovation process. In this section, we review the benefits and costs of bundling, focusing on how it affects incentives for R&D effort.

4.1. Bundling stages of procurement: insights from the economics literature

An R&D-based innovation process can be divided into two main stages: the R&D stage, where a solution is explored and a prototype is tested; and the production/commercialisation stage, where the industrial production of the proposed solution is carried out and commercialisation takes place. The two stages can be more or less integrated. At one extreme of the spectrum, we have complete separation, which occurs when one firm/organisation performs the R&D activity and another the industrial production. At the other extreme, we have full integration, which occurs when the same firm/organisation performs both the R&D and the industrial production in full coordination. Intermediate solutions are also possible, in which different firms/organisations coordinate among themselves (possibly by using contracts).

The problem can be looked at from a theoretical perspective by adopting the Principal–Agent framework (see Laffont and Martimort 2002 for a systematic treatment of the literature), where a Principal (the Public Authority (PA) in our case) can delegate two sequential tasks (R&D and industrial production) to the same Agent (i.e. if the tasks are 'bundled') or to two different Agents (i.e. if the tasks are 'unbundled'). The issue is relevant when contracts are incomplete, that is, when it is not possible to specify ex-ante the level (or type) of effort that is required from the Agent in each single contingency (either because effort is not 'verifiable' or because some contingencies are not verifiable, where the term 'verifiable' means that it can be observed by a Court of Law and therefore it can be contracted upon) that may arise during the execution of the contract. In the pursuit of their own interests, Agents may exert suboptimal effort, without fully taking into account the interests of the Principal. In these cases, bundling or unbundling tasks is important, as it affects the extra-contractual incentives of Agents.

This issue is important in procurement for R&D-based innovation and innovation processes. When contracting, the public procurer (the Principal) is typically unable to perfectly specify the level or type of effort that firms (Agents) should put into research, and may also be uncertain as to future demand for the product derived from the R&D effort. However, the procurer can specify some performance requirements that the innovation should satisfy, for example, in terms of system interoperability, energy efficiency, machine time and so on. In these circumstances, the inherent incentives that firms could have for undertaking research are affected by whether the task of undertaking R&D services is bundled or unbundled with the task of producing/commercialising the innovation.

Seminal papers by Hart (2003), Bennett and Iossa (2006) and Martimort and Pouyet (2008) – reviewed in Iossa and Martimort (2015) – have shown that bundling sequential tasks into one contract with a single Agent can be beneficial to the Principal (the procurer). This is the case when there exists a positive externality across the two sequential stages and it is not possible to specify in the contract all the tasks that need to be undertaken by the Agent or all the circumstances where a certain action is required (unbundling can instead be preferred to bundling in the presence of a negative externality). Experimental evidence has confirmed this hypothesis (Hoppe, Kusterer, and Schmitz 2013).

A positive externality exists if the firm's effort in the first stage reduces costs or increases quality (yielding higher profit for the firm) in the second stage. For example, in infrastructure procurement, putting more effort into design/construction at the building stage results in better infrastructure, which generates the positive externality of reducing the cost of managing and maintaining the infrastructure during the operational stage and yields higher quality of service. In this case, bundling induces the firm in the first stage to take into account how its efforts will affect the second-stage payoff. This generates extra-contractual incentives that increase the firm's willingness to put more effort into the first stage. Going back to our infrastructure example, anticipating that efforts made to design and build infrastructure will reduce operational costs, the firm in charge of both building and operation will choose to put more effort into design/construction than a firm who is only in charge of the building stage. As a result, the infrastructure will be of better quality and users will benefit from better services and/or lower costs. Bundling the two tasks into one contract with one single Agent thus results in an incentive effect that creates 'economies of scope' and leads to lower costs and higher quality.

In what follows, we analyse the potential benefits and costs of bundling the R&D stage with the production/commercialisation stage. Our focus is on the incentives that bundling provides for the R&D effort.

4.1.1. The relative benefit of bundling

The insights from the Principal–Agent literature have important implications for the design of efficient innovation procurement. With innovation procurement, there is moral hazard because the Agent's research effort is not verifiable by the public contracting authority, and contracts are incomplete because this effort is difficult to specify ex-ante and to describe in a contract (see also de Figueiredo and Teece 1996, who discuss the contractual hazard arising with technological innovation). Extra-contractual incentives are therefore important.

Consider first the case of an innovation that has a high degree of specificity for the public procurer and thus low market value, that is, it is valuable mainly to that procurer or within a limited-sized public sector (we shall hereafter refer to this case as 'high Public Authority specificity'). Innovations that increase the quality of public services or reduce their costs may have a high degree of (PA) specificity because of the nature of the public good or service to which the innovation is targeted (e.g. innovation in traffic management systems). If there is a positive externality across stages, as may be the case in knowledge-based sectors, then there is an incentive gain in bundling the R&D stage with the production/commercialisation stage. If the same firm undertakes both tasks, the knowledge acquired in the R&D stage will help it to lower the cost of producing the innovative solution, and it may lead to more cost-effective innovations.

In particular, bundling induces the internalisation of the positive externality, in the sense that it makes the firm at the R&D stage take into account how its research effort will affect the cost of producing the resulting innovation. Thus bundling incentivises greater effort when the externality is positive. Technological economies of scope that reduce the production costs of the proposed solution will reinforce this effect. Bundling R&D and production will also ease access to external funding, by reducing commercial risk and thus the risk premium required by the lender for financing a risky investment.

Furthermore, Che, Iossa, and Rey (2017) show that linking production to R&D services can provide extra-contractual incentives for research effort, even in the absence of positive externality or economies of scope. However, full bundling is generally not optimal. They consider the case when a project is valuable only to the procurer and its characteristics can be verified (for example, because it is possible to verify the level of energy efficiency of a proposed solution, or the machine time to complete a task) but the effort undertaken by the firm at R&D stage cannot be described or specified in the contract. In this setting, they show that biasing the tender for the production contract in favour of the firm proposing the best solution at the R&D stage, when the proposed project is of high value for the buyer, helps to reward good projects and provides extra-contractual incentives to put more effort into R&D.

Their key insight is that increasing the chance of the firm undertaking R&D to obtain lucrative production rights when it delivers a high-value innovation for the procurer gives the firm incentives to put additional effort into the R&D service. These additional incentives steams from the future rent that the innovating firm will be able to anticipate from the production contract. This 'carrot' can be particularly valuable when the innovation has a high degree of PA-specificity, as then using IPRs to reward innovation is of limited effect. In practice, a greater chance of obtaining the contract for the production/commercialisation of the innovation can be implemented by favouring the innovator at tender stage, giving additional points in the tender score.

However, full and unconditional bundling, as under an IP, is generally not optimal. If the firm is certain to obtain lucrative production rights even when the innovation has low value, the efforts it puts into research will decrease rather than increase, compared to the case where the two tasks are unbundled. Only if information, competency and processes are such as to ensure that the procurer is able to interrupt low-value projects before they reach implementation, may full bundling provide additional incentives to undertake R&D services.

Rewarding the innovator with contract rights is consistent with procurement practices observed in US defence procurement and described in Rogerson (1992, 1994). It is also in line with some recent legislation introduced in the US Defence industry, aimed to encourage the acquisition of innovative research and technology, through the expanded use of Other Transaction Authority (OTA).[16] OTA allows a prototype project to be awarded a follow-on production contract without the use of competitive procedures. The Department of Defence may opt for this solution provided that (i) competitive procedures were used in the initial prototype transaction award and (ii) the OTA contractor successfully completed the prototype project. OTA has been used in relation to the development of weapon systems.

Contract rights act as an incentive to achieve high-value innovations also in private procurement practice. Calzolari et al. (2015) find that, in German car manufacturing, obtaining a sole-production contract is the carrot used to incentivise suppliers in the design and investment process. As the designs are specific to the car manufacturers, and thus have little or no market value, the anticipation of production rights can be a particularly valuable way of stimulating research effort. With unbundling, the procurer does not commit to buying the resulting innovation, and this exposes the firm to the risk of hold-up: unable to sell its innovation in the wider market, the supplier undersells it to the procurer. Anticipating this, the supplier will underinvest in research effort.

Consider now the case of an innovation that has low PA-specificity (for the public procurer) and high market value. In this case, extra-contractual incentives for the R&D effort will arise from the opportunity to commercialise the innovation on the private market. The assignment of the IPRs to the firm (with the procurer retaining, of course, a licence of use) will provide it with incentives to put effort into research to deliver valuable and profitable solutions even if there is unbundling. However, underinvestment in R&D effort or an inefficient investment may still result, especially if the procurer and the market's preferences are not fully aligned. Nevertheless, the need of bundling as an instrument to provide extra-contractual incentives is weakened.

4.1.2. The relative cost of bundling

What are the risks and costs of bundling? For the benefits of bundling to materialise, the procurer must be able to translate its needs into well-defined project and performance specifications, so as to be able to terminate the contract if the project objectives are not met. If instead performance specifications are vague or difficult to verify, the firm would anticipate the possibility to obtain profitable production contracts even for low-value innovations, which would weaken its incentives to exert research effort (Che, Iossa, and Rey 2017).

Thus, the project value must be clearly observable and measurable via performance measures, before undertaking large-scale production. Tamada and Tsai (2007) show that, when verification of this kind is difficult because of asymmetric information problems, the first-stage firm has incentives to misreport project information so as to ensure that the project will not be discontinued and it will benefit also from the second-stage profit. As a consequence, bundling may cause low-value projects to be unjustifiably continued.

Furthermore, agency problems within governmental organisations may impede the stopping of low-value projects. This may happen even when these have been identified, albeit not perfectly verified. Risk adverse officials may fear that there will be a judicial challenge from the firm, and they may be perceived as responsible for project failure. They may also fear that stopping a project will be viewed as an admission of a mistake at the tender stage, which would incur a reputational loss.

Bundling also might make it more difficult for SMEs to access the market, as first emphasised by Timmermans and Zabala-Iturriagagoitia (2013). To the extent that SMEs may be in a difficult position to handle complex and long-term procurement contracts with an integrated commercialisation phase, bundling (such as that of IP) may discourage participation by SMEs. This point is best explained by comparing Figures 2 and 3. In Figure 2, the ranking of firms in terms of their efficiency at the R&D stage is the same as their ranking in terms of efficiency at producing the resulting solution. Firm A is the most efficient firm in both dimensions and we can expect that this firm will be selected at the tender stage, regardless of whether there is bundling or not.

Consider instead Figure 3, where Firm B is the most efficient at the R&D stage, whilst Firm C is the most efficient at producing, and suppose that Firm B is an SME. If the R&D stage and commercialisation are separated, the SME would probably win the PCP for the R&D services. If, however, the two stages are bundled, this firm would probably not win the bundled contract, as it is not sufficiently competitive in production.[17] As most of the profits are realised in the construction phase, where the contract value is highest, a firm efficient in production (Firm C in our example) would most likely get the contract. This firm, could of course, subcontract the R&D services to the SME (Firm B), but with high-bargaining power of the larger production firm (Firm C), it is unlikely that the SMEs would manage to secure rewarding contract terms. Bundling thus changes the characteristics of the firm that is likely to win the tender, and this may discourage SMEs from participating to the auction altogether, as they anticipate that they will not be able to compete in both the innovation and production dimensions.

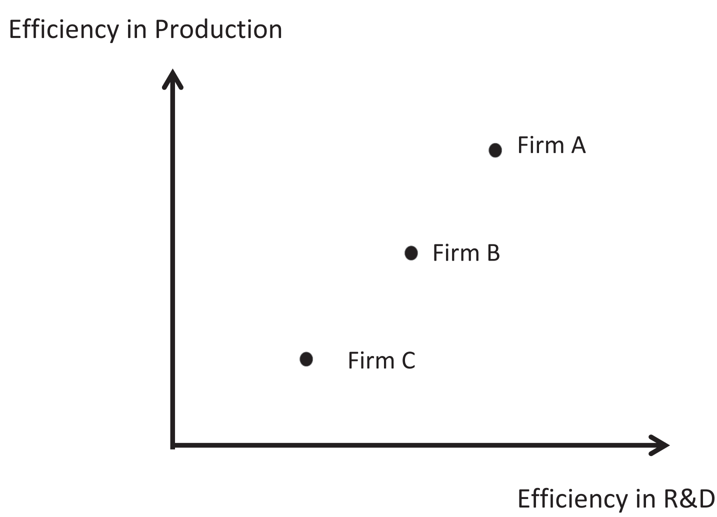

Figure 2. The two dimensions of competition: the case of correlated ranking.

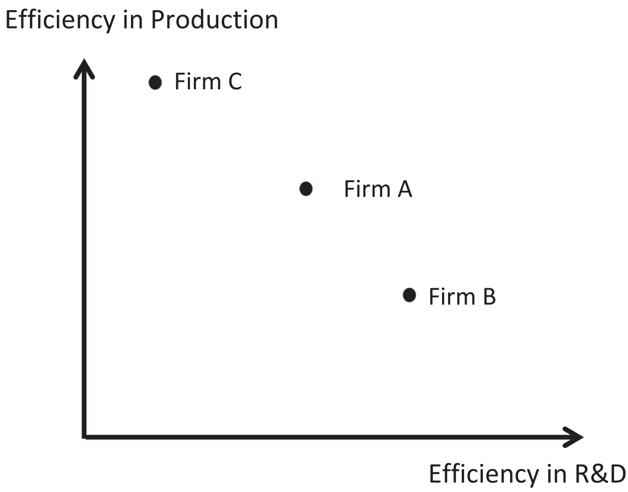

Figure 3. The two dimensions of competition: the case of *uncorrelated* ranking.

When fixed costs are high, investment can be difficult to recover because the knowledge acquired is specialised and often customised to reflect specific market needs. This may discourage entry, especially if the entrants are SMEs with limited funding to cover the investment costs. In this regard, the risk-sharing approach of PCPs can help SMEs to innovate, by reducing the amount of private investment they need to enter the market.

We also know that long-term partnerships with a single partner for a high-contract value can be a threat to fair competition in the market. Secured by a long-term production contract with a procurer, the firm may gain a lock-in position and long-term advantage over its competitors. Similar concerns apply to the bundling of R&D and production activities: by increasing dependency on one vendor, lock-in effects may be exacerbated. This may be a problem in some areas, such as ICT systems, where many buyers are 'locked' because detailed knowledge about how the system works is available only to the supplier, so that when they need to buy new components or licences only the latter can deliver[18] (European Commission 2013). Moreover, buyers find it difficult to change supplier after the expiration of the contract, because not all the essential information or technologies for production are available for efficient takeover by another supplier. Hence, partnerships must be structured so that they do not lead to anti-competitive effects and supplier lock-in. Finally, the European Directive 2014/24/EU on Public Procurement currently leaves unspecified many important aspects of IP, such as the duration of the partnership, or its value – apart from the statement that it should not be 'excessive'.[19]

4.1.3. Benefit vs costs: the trade-offs

When we consider the alternative to bundling, namely a PCP (possibly) followed up by a PPI, the benefits and risks are somewhat reversed. For innovations with high PA-specificity, the separation between R&D and production does not allow the internalisation of the externalities across stages, but it helps the public procurer to filter technological risks before committing to the purchase. Compared to an IP, a PCP clearly gives more leverage to the procurement authority not to continue with a PPI procedure a project that is not considered worth of further public financing. This helps solve project verification problems and the agency problem in governmental organisations, but it may make access to financing more difficult.

For those innovations with low PA-specificity but high market value, extra-contractual incentives under PCP are provided by the market, as the firm anticipates that greater research effort will result in more profitable innovative solutions. The assignment of significant property rights to the firm that characterises PCPs (typically the public sector retains a licence of use) will therefore help to provide strong incentives. Finally, PCP leaves more space for SMEs to express their innovation potential, which otherwise would be restricted by their limited ability to undertake large-scale production.

Our reasoning above suggests that in cases where PA-specificity is low[20] there is a great potential for a 'dual approach' to innovation (where both private and public objectives are pursued, as these are aligned). Leaving IPRs to the firm can bring strong incentives for the firm to develop efficient solutions that will be valuable not only for the public sector, but also for the private sector. Anticipating the gain from the commercialisation of its developed solution, firms in the market will have strong incentives to compete for procurement contracts, and to contribute financially to the project development costs.

In the light of the above considerations, we summarise our insights in Table 2. Specifically, the scope for IPs will be greater when:

(i) bundling R&D and production is beneficial, as there are significant technical economies of scope or other positive externalities between R&D and production;
(ii) the innovation is expected to have a high level of *PA specificity*: that is, the innovation is valuable for the public procurer but there is no significant demand for it from the private sector;
(iii) the value for the procurer of the resulting innovation is easy to verify, allowing performance specifications to be clearly described in the tender documents and used to decide whether to award the production contract to the same firm or not. This also reduces the risk of funding low-value projects;
(iv) SMEs have a limited role in the market addressed by procurement.

On the other hand, when none of the above conditions hold, it is preferable to separate the two stages, and use PCP for the R&D stage. With low PA-specificity, the firms in the PCP tender will have strong incentives for research effort thanks to the prospect of profitable market opportunities and the acquisition of IPRs.

In the intermediate situations where some but not all of the conditions hold, there will be a trade-off and the choice of the instrument will have to be made after an accurate analysis of the market conditions and the type of innovation. For example, when only conditions (i), (ii) and (iii) hold, bundling of R&D and production will help to stimulate R&D effort. However, it will also be detrimental to SMEs in the market and it will be associated with a high risk of long-term supplier lock-in. When conditions (i), (ii) and (iv) hold but (iii) does not, then bundling will increase the risk that unsuitable projects are given the go-ahead and it will have ambiguous effects on research effort. Unbundling may then be preferred.

5. The risk of procurement failure

In this section, we briefly discuss how the capacity and incentives of the public sector affect the choice and impact of procurement and how this is relevant for innovation procurement. As

Table 2. Suitable conditions for an innovation partnership or pre-commercial procurement.

Suitable conditions for an IP	Suitable conditions for PCP (possible follow-up PPI)
High level of PA-specificity	High market value/private demand
High-technological economies of scope or positive externalities between R&D and production	No significant economies of scope or positive externalities between R&D and production
No significant role for SMEs	SMEs present in the market
Limited potential market competition	Significant potential market competition
No significant risk of market foreclosure and supplier lock-in	Desirable to boost market competition in order to overcome supplier lock-in
Strong institutional incentives within the procurer organisation	Agency problems and weak incentives within procurer organisation
Clear performance targets and project value observable and measurable ex post	Project value difficult to observe and measure ex post

Source: our elaborations.

emphasised by the OECD (2011), to be successful, procurement of innovation requires significant capacity development in the public sector and a considerable break with traditional and risk-averse procurement practices.

In terms of capacity, the public procurer needs to be able to make an accurate internal assessment and identify its procurement needs and the functional requirements that adequately reflect these needs. The public procurer must also design the tender optimally so that it provides firms with adequate incentives to participate and effectively compete for the procurement contract. Aspects of the tender design, such as the technical and financial pre-requisites for participation (i.e. pre-qualification), the award criteria and the criteria weights, the number of lots and the tender format, are all key decisions that have a great impact on procurement performance. Specialised skills are needed to choose the appropriate tender and contract design, as this must take into account features including the existing competition in the market, the characteristics of the pool of potential suppliers, the type and complexity of the good, work or service being acquired, besides legal principles and available contract management ability and resources.

Decarolis et al. (2017b) have recently estimated the impact of procurer competency on the performance of procurement contracts. They undertake an empirical analysis of the impact of public buyers' competence on public procurement outcomes in the US, combining three large data sets over the interval 2010–2015 and tracking every federal contract worth more than $2500, as well as every follow-on contracting action, such as a renewal or modifications. From these data they obtain measures of past time delays and cost overruns, over the original contract amount, and information on the quality of the bureau in terms of incentives provided, skills acquired and internal cooperation, which they use to create a measure of current competency. They show that competence at the bureau level is associated in a statistically significant way with better time and cost performance. The effect is quantitatively relevant: a 0.08 points increase in competence (corresponding to increasing bureau competence from its 10th percentile to its 90th percentile) implies an enhancement in both cost and time performance, respectively, of 143% and 114%. It is therefore central that at a time when procurement policy is seen as a strategic tool to foster innovation and address societal needs, public procurers prove to have the skills to perform their job effectively.

The problem of procurer competency is even more significant for innovation procurement, as the design of tenders that are either for R&D services or for the provision of innovative goods or services is particularly complex, because of the risky nature of innovation. Lack of capacity may result in wrong technical or performance specifications, award criteria and weights that do not reflect the priorities of the procurer, lack of participation and insufficient uptake of the innovation.

Furthermore, procurement officials must have incentives to bear the high risks that innovation-oriented procurement brings. For procurers to be willing to take these greater risks, the presence of explicit or implicit incentives for officials in public procurement offices become key. Relying on the intrinsic motivation of procurers is unlikely to suffice, as procurers are typically risk-averse and thus disinclined to take risks unless there are explicit incentives. Career concerns may also disincentivise risk taking, if procurers face a reputational loss when procurements fail and no career gains when they succeed. Thus, the organisation of governments and public institutions wanting to undertake innovation-oriented public procurement needs to be structured in order to ensure that the incentives of procurement officers are aligned with those of the organisation.

Recent empirical evidence confirms the centrality of procurer's competence and incentives. In another recent paper, Decarolis et al. (2017a) empirically explore the relationship between quality scores of public buyers involved in the procurement of R&D contracts for the US federal agencies and the outcomes of these contracts in terms of patent registrations. Using a generalised propensity score approach, they graphically show that the probability for an R&D contract to produce at least one patent is positively associated with the bureau characteristics, which separately capture competence, skills, cooperation and incentives. Furthermore, they investigate the causal effect on contract patentability, and find that an increase of 10% in the measures of bureau competencies increases the probability that an R&D contract generates at least a patent from 9.7% up to 15.9%, depending on the specific characteristic considered.

6. Conclusions

In this paper, we have discussed a range of public policy instruments that can encourage the creation and uptake of innovations for the delivery of higher quality and more cost-efficient public services. By highlighting the central role played by bundling R&D and production/commercialisation on the incentives of the firms in the presence of asymmetric information, the paper has argued that the choice of the procurement instrument to buy R&D services or innovative goods and services should depend on the characteristics of the market and of the innovation. Factors such as the presence of positive externalities or economies of scope between R&D and commercialisation, the level of the innovation's PA-specificity, the technological risk, the role of SMEs in the relevant market, and the degree of contractibility and verifiability of the innovation, should direct how procurers and policymakers choose one instrument or another.

In particular, we argued that the bundling of the R&D stage and the production phase – such as under an IP – is beneficial when: (i) there are significant technical economies of scope or other positive externalities between R&D and production; (ii) the innovation is highly valuable for the public procurer but there is no significant demand for it from the private sector; (iii) the value for the procurer of the resulting innovation is easy to verify; and (iv) SMEs have a limited role in the market addressed by procurement. When none of the above conditions hold, it is preferable to separate the two stages, and use PCP for the R&D stage.

We have also highlighted how the success of these instruments and of procurement, in general, may be undermined by lack of appropriate skills, incentives and competencies within the public sector, as also suggested by recent empirical work on the impact of procurer competency on procurement outcomes. Lack of skills, incentives and cooperation may result in inappropriately designed tenders and contracts, with delays, increase in costs, and poor results. Compared to traditional procurement practices, innovation-oriented public procurement makes capacity building even more central to the success of the procurement process.

Necessary conditions for innovation-oriented public procurement to be successful are therefore the presence of management practices to deal with the risks of innovation procurement and incentive schemes to motivate procurers to take appropriate risks. A multi-disciplinary approach, combining economic, engineering, managerial and legal knowledge, is needed to reshape many procurement offices currently too focused on ensuring the correct application of the law, rather than on the strategic design and efficient use of public procurement.

This takes us back to the importance of data gathering and performance evaluations in the public sector. The outcomes of officials' decisions should be assessed, and used to provide public procurers with monetary and non-monetary rewards when they successfully complete projects that satisfy long-term objectives of the organisation. Procurers need to anticipate career gains when they take the initiative and obtain formal recognition, and visibility. Continuous training should be arranged so as to ensure their professional and technical development.

The push towards a greater use of innovation procurement must therefore go one to one with the recognition that there is great need to create capacities and expertise in procurement offices.

Notes

1. http://ec.europa.eu/trade/policy/accessing-markets/public-procurement/
2. For example, innovation explained up to 80% of GDP growth in the US during the period 1909–1959 (Solow 1957) and 68% for the period 1929–1982. The key role of innovation for European growth is emphasised in a number of documents; see European Commission (2014) as a recent example. There are a number of definitions for innovation. For the purpose of this study, we shall focus on the technological innovation: the transformation of an

idea into a marketable product or service, typically encompassing a technological R&D and a commercialisation phase.

3. From 1945 to 2008, 59 collaborative defence procurement programmes were launched in Europe. Heuninckx (2008) reports that operational benefits were barely achieved, as compromises required by harmonisation usually led to increased cost and delays.
4. Assigning well-defined intellectual property rights may sometimes be difficult, because of the characteristics and complexity of the innovation. Anticipating problems with the attribution of property rights, firms may lack appropriate incentives to invest in R&D. Litigation and weak enforcement are a widespread phenomenon (see Scotchmer and Maurer 2004).
5. The latter, however, views PCP as a source of R&D funding and thus a supply-side policy instrument in relation to innovation, rather than a demand side one.
6. See http://www.innovation-procurement.org/projects/ict/
7. For a project description, see http://www.vinnova.se/en/innovationsupphandling/Projects/ITS-Innovation-Stockholm-Kista/; see also Bedin, Decarolis, and Iossa (2015) for more details on the PCP process.
8. See http://www.thalea-pcp.eu/
9. Notice that the acronym PPI is sometimes used to refer generically to public procurement of innovation, which includes PCP and PPI. For further information, see https://ec.europa.eu/digital-agenda/en/public-procurement-innovative-solutions
10. On the complementarity between PCP and PPI, see also Edquist and Zabala-Iturriagagoitia (2015).
11. See https:// www.innovation-procurement.org/
12. https://en.wikipedia.org/wiki/Lockheed_C-5_Galaxy
13. http://ted.europa.eu/udl?uri=TED:NOTICE:281836-2013:TEXT:EN:HTML
14. Note that a procurement project in the spirit of the IP was implemented in the US defence sector (Rogerson 1992, 1994), where the tender competition for the best prototype was followed by a non-competitive production stage, where the winner of the R&D competition was virtually certain to be awarded the follow-on contract.
15. London: Transport equipment and auxiliary products to transportation, Periodic indicative notice – utilities Supplies, number 2016/S 217-395943.
16. Section 815, Amendments to Other Transaction Authority, of the National Defence Authorization Act for Fiscal Year 2016, signed into law on 25 November 2015.
17. This argument does not take into account the possibility that an SME could undertake a joint venture with a larger firm. Joint ventures may facilitate SME participation but they are costly and time-consuming, and the issue remains: empirical evidence shows that the large size of contracts is probably the most important barrier for SMEs accessing public procurement. A survey conducted for the EC covering 296 European procurers and 887 European companies participating in public procurement between 2008 and 2012showed that whilst SMEs won around 60% of contracts below 1 million euro, they won only 30% of contracts above 5 million euro. The regression analysis undertaken in the study confirms that the higher the value of the contract, the lower the likelihood that SMEs are awarded the contract. The value threshold above which SMEs are seemingly disadvantaged is at around 300,000 euro. See GHK (2010).
18. In a study commissioned by the European Commission, Bedin, Decarolis, and Iossa (2015) investigate the economic impact of PCP, compared to other procurement methods that differ from PCP in some key dimensions. They collect evidence on eight European PCP tenders undertaken in Europe after 2011 and compare them with a sample of 32 cases of non-PCP procurements undertaken in Europe in the same period. Using a methodology based on Ordinary Least Squares (OLS) and Nearest Neighbour Matching (NNM) estimators, they find convincing evidence of a positive association between PCP and reduced lock-in. In their study, PCP cases witnessed SMEs participation, and in the 87.5% of cases, SMEs were also awarded the PCP contract as single bidders or as lead partners in consortium/entity groupings. Furthermore, they find empirical evidence to show that PCP increases both the number of SMEs that participate and the number that are awarded contracts, compared to conventional joint procurement of R&D services and supply.
19. For a survey on the ICT's 'attitude' of 244 procuring authorities in the EU Member States, see: http://cordis.europa.eu/fp7/ict/ssai/docs/study-action23/study44-survey1results.pdf
20. The ICT sector provides examples of ICT systems, developed for the public sector, finding important external applications in the private sector. The PA-specificity of these innovations is therefore low. For example, the origins of the Internet date back to research commissioned by the United States government in the 1960s to build communication via computer networks. The precursor network, the ARPANET, served as the backbone for interconnection of regional academic and military networks in the 1980s (Wikipedia). Other examples include the new robot algorithm for the iRobot Project, commissioned by the US Advanced Research Development Agency (DARPA) to develop a mobile tactile robot, which was successfully commercialised in the market, or the US supercomputing procurement program which led to the development of the first processor on a chip and set the basis for personal computers (for further examples, see Ramboll 2008).

Acknowledgements

We thank the editor and an anonymous referee of this journal for their useful comments on an earlier version of this paper. We also wish to thank Silvia Vannutelli for very helpful research assistance.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Elisabetta Iossa http://orcid.org/0000-0002-1010-3789
Paola Valbonesi http://orcid.org/0000-0003-1250-1622

References

Aho Group. 2006. "Creating an Innovative Europe." Report of the Independent Expert Group on R&D and Innovation Appointed Following the Hampton Court Summit and Chaired by Mr Esko Aho, European Communities. Luxembourg: Office for Official Publications of the European Communities.

Aschhoff, B., and W. Sofka. 2009. "Innovation on Demand – Can Public Procurement Drive Market Success of Innovations?" *Research Policy* 38: 1235–1247.

Bedin, S., F. Decarolis, and E. Iossa. 2015. "Quantifying the Impact of PCP in Europe Based on Evidence from the ICT Sector." Report Commissioned by DG Connect, European Commission.

Bennett, J., and E. Iossa. 2006. "Building and Managing Facilities for Public Services." *Journal of Public Economics* 90: 2143–2160.

Bos, L., and S. Corvers. 2006. "Pre-commercial Public Procurement: A Missing Link in the European Innovation Cycle Public Needs as a Driver for Innovation." Extracts of Expert Group Report Published by DG INFSO (Directorate General for Information Society and Media, European Commission).

Cabral, L., G. Cozzi, G. Spagnolo, V. Denicolò, and M. Zanza. 2006. "Procuring Innovation." In *Handbook of Procurement*, edited by N. Dimitri, G. Piga, and G. Spagnolo, 483–528. Cambridge: Cambridge University Press.

Calzolari, G., L. Felli, J. Koenen, G. Spagnolo, and K. O. Stahl. 2015. "Trust, Competition and Innovation: Theory and Evidence from German Car Manufacturers." CESifo Working Paper No. 5229.

Che, Y. K., E. Iossa, and P. Rey. 2017. "Prizes vs Contracts as Incentive for Innovation." CEPR Discussion Paper No. 11904, London.

Decarolis, F., G. de Rassenfosse, L. Giuffrida, E. Iossa, V. Mollisi, E. Raitieri, and G. Spagnolo. 2017a. "Buyer Competence and Innovation Procurement." *Mimeo*.

Decarolis, F., L. Giuffrida, E. Iossa, V. Mollisi, and G. Spagnolo. 2017b. *Buyer Quality and Procurement Outcomes: Explorative Evidence from the US*. Stockholm: Mimeo, SITE.

de Figueiredo, J. M., and D. J. Teece. 1996. "Mitigating Procurement Hazards in the Context of Innovation." *Industrial and Corporate Change* 5 (2): 537–559.

Edler, J. 2007. "Demand-based Innovation Policy." Manchester Business School Working Paper No. 529. Manchester Business School, Manchester.

Edler, J. 2013. "Review of Policy Measures to Stimulate Private Demand for Innovation: Concepts and Effects." Nesta Working Paper No. 13/13.

Edler, J. 2016. "The Impact of Policy Measures to Stimulate Private Demand for Innovation." In *The Handbook of Innovation Policy Impact*, edited by J. Edler, P. Cunninchgham, A. Gok, and P. Shapira, 318–354. Cheltenham: Edward Elgar.

Edler, J., and L. Georghiou. 2007. "Public Procurement and Innovation – Resurrecting the Demand Side." *Research Policy* 36: 949–963.

Edquist, C., and L. Hommen. 1999. "Systems of Innovation: Theory and Policy from the Demand Side." *Technology in Society* 21: 63–79.

Edquist, C., L. Hommen, and L. Tsipouri. 2000. "Policy Implications." In *Public Technology Procurement and Innovation*, edited by C. Edquist, L. Hommen, and L. Tsipouri, 301–311. Boston, MA: Kluwer Academic.

Edquist, C., N. S. Vonortas, J. M. Zabala-Iturriagagoitia, and J. Edler, eds. 2015. *Public Procurement for Innovation*. Cheltenham: Edward Elgar.

Edquist, C., and J. M. Zabala-Iturriagagoitia. 2012. "Public Procurement for Innovation as Mission-oriented Innovation Policy." *Research Policy* 41 (10): 1757–1769.

Edquist, C., and J. M. Zabala-Iturriagagoitia. 2015. "Pre-commercial Procurement: A Demand or Supply Policy Instrument in Relation to Innovation?" *R&D Management* 45 (2): 147–160.

European Commission. 2005. *Public Procurement for Research and Innovation*. Brussels: European Commission.

European Commission. 2007. "Pre-commercial Procurement: Driving Innovation to Ensure Sustainable High Quality Public Services in Europe." Commission Staff Working Document Accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions COM (2007) 799 final, Brussels.

European Commission. 2013. "Against Lock-in: Building Open ICT Systems by Making Better Use of Standards in Public Procurement." Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2013) 455 final.

European Commission. 2014. "Research and Innovation as Sources of Renewed Growth." Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Research and Innovation as Sources of Renewed Growth, COM (2014) 339 final

European Commission Directive 2014/24/EU of the European Parliament and Council on Public Procurement and Repealing Directive 2004/18/EC

GHK. 2010. "Evaluation of SME's Access to Public Procurement Markets in the EU. A Study Commissioned by the European Commission." DG Enterprise and Industry.

Hart, O. 2003. "Incomplete Contracts and Public Ownership: Remarks, and an Application to Public-Private Partnerships." *Economic Journal* 113: C69–C76.

Heuninckx, B. 2008. "A Primer to Collaborative Defence Procurement in Europe: Troubles, Achievements and Prospects." *Public Procurement Law Review* 17 (3): 123–145.

Hoppe, E., D. Kusterer, and P. W. Schmitz. 2013. "Public-Private Partnerships Versus Traditional Procurement: An Experimental Investigation." *Journal of Economic Behavior and Organization* 89: 145–166.

Iossa, E., and D. Martimort. 2015. "The Simple Micro-economics of Public Private Partnerships." *Journal of Public Economic Theory* 17 (1): 4–48.

Kok, W. 2004. "Facing the Challenge: The Lisbon Strategy for Growth and Employment." Report by the High Level Group Chaired by W. Kok. Luxembourg: Office for Official Publications of the European Communities.

Laffont, J. J., and D. Martimort. 2002. *The Theory of Incentives: The Principal Agent Model*. Princeton: University Press.

Lember, V., R. Kattel, and T. Kalvet. 2014. "Public Procurement and Innovation: Theory and Practice." In *Public Procurement, Innovation and Policy, International Perspectives*, edited by V. Lember, R. Kattel, and T. Kalvet, 13–34. Berlin: Springer.

Martimort, D., and J. Pouyet. 2008. "To Build or Not to Build: Normative and Positive Theories of Public–Private Partnerships." *International Journal of Industrial Organization* 26 (2): 393–411.

Martin, S., and J. T. Scott. 2000. "The Nature of Innovation Market Failure and the Design of Public Support for Private Innovation." *Research Policy* 29: 437–447.

OECD. 2011. *Demand Side Innovation Policy*. Paris: OECD.

OECD. 2014. "Intelligent Demand: Policy Rationale, Design and Potential Benefits." OECD Science, Technology and Industry Policy Papers No. 13., Paris: OECD.

Ramboll Management Consulting. 2008. "Opportunities for Public Technology Procurement in ICT-related Sectors in Europe." Final Report Prepared for the European Commission.

Rigby, J. 2016. "The Impact of Pre-commercial Procurement on Innovation." In *Handbook of Innovation Policy Impact*, edited by J. Edler, P. Cunningham, A. Gök, and P. Shapira, 382–402. Cheltenham: Edward Elgar.

Rogerson, W. P. 1992. "Contractual Solutions to the Hold-up Problem." *The Review of Economic Studies* 59: 777–794.

Rogerson, W. P. 1994. "Economic Incentives and the Defense Procurement Process." *Journal of Economic Perspectives* 8: 65–90.

Scotchmer, S., and S. M. Maurer. 2004. "Procuring Knowledge, Intellectual Property and Entrepreneurship." *Advances in the Study of Entrepreneurship, Innovation and Growth* 15: 1–31.

Solow, R. 1957. "Technical Change and the Aggregate Production Function." *The Review of Economics and Statistics* 39: 312–320.

Tamada, Y., and T. S. Tsai. 2007. "Optimal Organization in a Sequential Investment Problem with Principal's Cancellation Option." *International Journal of Industrial Organization* 25: 631–641.

Timmermans, B., and J. M. Zabala-Iturriagagoitia. 2013. "Coordinated Unbundling: A Way to Stimulate Entrepreneurship Through Public Procurement for Innovation." *Science and Public Policy* 40 (5): 674–685.

Uyarra, E. 2016. "The Impact of Public Procurement of Innovation." In *Handbook of Innovation Policy Impact*, edited by J. Edler, P. Cunningham, A. Gök, and P. Shapira, 355–381. Cheltenham: Edward Elgar.

Von Hippel, E. 2005. *Democratizing Innovation*. Cambridge, MA: MIT Press.