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Public procurement as an innovation policy: Where do we stand? ☆

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ABSTRACT

Scholars and policymakers have long recognized the potential of public procurement as an industrial policy tool to incentivize innovation. However, it remains unclear to what extent this potential has been realized and what measures should be implemented to maximize performance. This paper surveys the economic literature on public procurement of innovation (PPI) to take stock of this debate. We discuss the existing research on four broad questions: i) Does PPI spur innovation? ii) How should PPI be designed to best spur innovation? iii) What barriers hinder the implementation of PPI? iv) What is the role of PPI in the innovation policy mix? We conclude that PPI can be an effective innovation policy, but that further investigation is needed for a more solid assessment. We highlight the areas where additional research is most needed and discuss policy implications for current global challenges.

1. Introduction

Market economies tend to underprovide innovation, mainly because private firms face financial constraints and do not internalize the social benefits of their innovative efforts. As a result, innovators underinvest in research and development (R&D), primarily early-stage (Nelson, 1959; Loury, 1979; Griliches, 1992; Jones and Williams, 1998). Considering the crucial role that innovation plays in fostering productivity, competitiveness, and, ultimately, economic growth (Jaffe, 1986; Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1997; Griliches, 1998; Moretti et al., 2025), public intervention is needed to address such market failure

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and strengthen firms' incentives to innovate (Arrow, 1962). This issue seems to be especially relevant at times where the global community is facing an unprecedented combination of challenges, including climate change, pandemics, and disruption of supply chains amidst increasing geopolitical turmoils. Addressing these challenges requires the development and adoption of innovative technologies. Therefore, the role of innovation policies and, more broadly, industrial policies, seems more relevant than ever (Van Reenen, 2020; Mazzucato, 2021; Rodrik, 2022).

The recently published Draghi report (Draghi, 2024) suggests that industrial policies focused on innovation and technology adoption will be essential for the European Union (EU) to address its competitiveness and productivity gap relative to major foreign competitors, the United States (US) and China, where such policies have been more aggressive.[4] At the same time, while the traditional view is that industrial policy has been ineffective and harmful by distorting competition to support "loser" incumbents and national champions, a more positive view is emerging among scholars (Aghion et al., 2015; Tirole, 2017, 2024; Lane, 2020; Juhász et al., 2024) and policymakers (OECD, 2024). Such a "New Industrial Policy" perspective suggests that, if well-designed, industrial policies can be effective and pro-competitive.

In this context, this paper focuses on the role of public procurement as a "New Industrial Policy" tool to incentivize innovation. Governments are large (if not the largest) buyers in many sectors and can leverage their purchasing power to pursue policy objectives beyond value for money.[5] Therefore, when it comes to innovation, in addition to ensuring intellectual property rights (Jaffe, 2000) and implementing supply-side policies such as R&D tax credits and direct subsidies for private R&D initiatives (Nemet, 2009; Acemoglu et al., 2012, 2016; Costantini et al., 2015), governments can exploit their procurement decisions to directly promote new ventures and spur innovation (Geroski, 1990; Maurer and Scotchmer, 2004; Cabral et al., 2006; Iossa et al., 2018). In fact, several procurement programs and policies are implemented across countries to promote innovation, alongside sustainability and the development of small businesses (OECD, 2017b). By demanding innovation to satisfy public needs, public procurement can create lead markets for innovative goods and services at a scale that makes the R&D investments worthwhile for the suppliers. In addition, by acting as an early user of the innovation, governments can absorb the risks associated with deploying novel and unproven technologies. This early adoption may provide important lessons to innovators, helping them refine their products and strategies in preparation for large-scale commercialization.[6] While these insights cannot directly de-risk the upfront investment ex-ante, they can enhance the innovator's confidence in subsequent ventures and accelerate the market diffusion of innovations ex-post.

Thus, public procurement of innovation (henceforth PPI) has the potential to incentivize R&D investments. This potential has been long recognized by management scholars (see, e.g., Edquist and Hommen, 1999, Edquist et al., 2015) and is increasingly acknowledged by policymakers (see, e.g., OECD, 2017a). In fact, the Draghi report highlights various ways to exploit public procurement as part of the competitiveness strategy for the EU, including to support decarbonization technologies and aggregate demand to leverage scale in the purchase of vaccines, gas, defense technologies, and critical materials.

Despite its potential, there is currently no clear understanding of the actual performance of PPI as a driver of innovation, nor on the measures needed to improve its effectiveness. Enhancing this understanding is crucial to evaluate whether it is worthwhile for governments to invest more commitment and resources in PPI as an industrial policy tool within the innovation policy package. This is especially important in times of societal challenges where the role of "mission-oriented" public procurement (Geroski, 1990; Maurer and Scotchmer, 2004; Scotchmer, 2004; Mazzucato, 2011) might be particularly relevant.[7]

This paper aims to address this lack of knowledge by providing an updated survey of the economic literature on PPI. The survey focuses on four overarching questions. First, does PPI spur innovation—i.e., what is the evidence for PPI as a driver of innovation, and under what circumstances is it effective? Second, how should PPI be designed to best spur innovation? Third, what barriers hinder the implementation of PPI, and what is the role of public purchasing agencies and officials? Fourth, what is the role of PPI in the innovation policy mix—i.e., when is procurement "more effective" than other instruments in incentivizing innovation, and why?

The insights derived from our survey can be summarized as follows.

- *Does PPI spur innovation?* Existing research, though limited, indicates that PPI can foster innovation. Firm-level evidence suggests that, however, it tends to encourage incremental more than radical innovations, thus promoting technology diffusion rather than breakthrough technological advancements. PPI is particularly effective for young, small, or financially constrained firms, especially if they are given the flexibility to explore and propose different innovative solutions. An emerging literature finds evidence of the effectiveness of PPI in promoting green innovation. Industry-level evidence suggests that public demand shocks are an important driver of innovation, for example in the healthcare sector, and that PPI has positive spillovers both within and across countries.
- *How should PPI be designed to best spur innovation?* The existing literature suggests that there is no one-size-fits-all for the design of PPI, but that optimal choices depend on the characteristics of the technology and the market, as well as the level of information and abilities of the procurer. Several insights can be derived. First, bundling R&D and commercial phases is relatively more advantageous when economies of scope are strong and the innovation is specific to the public sector. Second, granting the buyer

[4] Industrial policies are on the rise across countries (see e.g., Criscuolo et al., 2022). Examples of large initiatives are "Made in China 2025", the "European Green Deal Industrial Plan", and the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act and the Inflation Reduction Act (IRA) in the US.

[5] Public procurement accounts for 12.9% of GDP in high-income countries (OECD, 2023).

[6] Moving innovations from market readiness to full commercial scale can be particularly challenging due to a combination of technical and market risks and lack of funding—sometimes referred to as the "valley of death" (see, e.g., Nemet et al., 2018).

[7] The recent COVID-19 pandemic and the Ukraine war have shown the importance of public procurement, for example in purchasing vaccines, medical equipment, and gas.

enhanced decision-making latitude is beneficial when the innovation's quality and the innovator's effort are harder to contract upon, provided the buyer has adequate capabilities. Third, technology-neutral mechanisms can facilitate the exploration of innovative solutions, but at a potential cost in terms of excessive rents left to suppliers. Fourth, the effect of increased competition on innovation is ambiguous and depends on the uncertainty in contract specifications and supplier characteristics. Fifth, by boosting demand size, procurement centralization can enhance the impact of PPI as a catalyst for innovation.

- *What barriers hinder the implementation of PPI?* A research agenda has recently emerged on the importance of buyer capabilities as a major determinant of PPI performance. The existing literature provides three main pieces of evidence: First, the (lack of) capabilities of procurement personnel are important. Second, management practices within the contracting unit are relevant. Third, time and resource constraints for procurement personnel are particularly harmful.
- *What is the role of PPI in the innovation policy mix?* Existing research evaluating the performance of PPI relative to and in combination with other innovation policies reports mixed evidence. PPI may outperform supply-side instruments, particularly for projects with high societal value and where limiting crowding out is beneficial, but only if it is well-designed. Evidence on the combination of PPI with supply-side policies is inconclusive, but highlights that whether PPI will be more or less effective in a policy mix than stand alone will crucially depend on the details of the design.

The surveyed research overall suggests that, if well-designed, PPI can function as an innovation policy. However, it also underscores the need for further investigation in several areas.

Our work aims to fill the gaps left by existing surveys. Recent surveys on the economics of innovation, particularly Bloom et al. (2019) and Bryan and Williams (2021), largely ignore the role of public procurement. Both surveys discuss evidence on instruments such as tax incentives, intellectual property rights, competition and labor market policies, and research grants. However, they only consider procurement programs similar to grants (such as the US Small Business Innovation Research Program) in a tangential manner. The only two surveys we are aware of on the economics of PPI, that is Iossa et al. (2018) and Cabral et al. (2006), are more limited in scope and have different aims. Primarily based on lessons from contract theory, Iossa et al. (2018) focus on a particular design question—namely, whether the R&D and commercialization phases of PPI should be bundled or not—to assess PPI instruments adopted within the EU. Cabral et al. (2006) consider additional issues—e.g., on the design of research contests and standards—relying on lessons from contest and innovation theory to provide practical recommendations on PPI implementation. Neither of these two surveys provides a discussion of the empirical literature on PPI. We aim to fill these gaps by providing an updated review that also considers PPI performance and measures to improve it.

The rest of the paper is organized as follows. Section 2 introduces the subject matter and provides a working definition of PPI. Section 3 reviews the literature on existing evidence on PPI performance. Section 4 surveys the scholarship on the optimal design of PPI, while Section 5 discusses the barriers to implementation, with a particular focus on the role of public buyer capabilities. Section 6 documents the role of PPI in the broader policy mix for innovation. Section 7 concludes with a summary of takeaways from the literature and outlines priority areas for future research. The Appendix provides a classification and characterization of the main PPI instruments currently adopted.

2. Background: what is PPI?

Innovation policies can be broadly classified into supply-side (or "technology-push") and demand-side (or "market-pull"). Supply-side policies aim to incentivize innovation by providing ex-ante financial support for R&D investment, thereby reducing the cost of the *input* of innovation. Prominent examples include government-sponsored R&D grants, tax credits for companies investing in R&D, basic-research funding for higher-education institutes, and training programs. In contrast, demand-side policies aim to foster innovation by creating demand and markets for the *output* of innovation, thereby increasing the payoffs for successful innovations. Key examples of demand-side instruments are intellectual property rights, tax credits for consumers of new technologies, technology mandates, regulatory standards, taxes on competing technologies, and, notably, PPI.[8]

PPI Following Edquist and Hommen (2000), we define PPI as the process by which "[...] 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 organization(s) willing to produce, supply and sell the products being purchased". While PPI shares some similarities with government-sponsored R&D grants, it typically involves a higher degree of conditionality. This means that the government retains decision rights on which projects to finance, thereby guiding technological development and limiting the spectrum of innovative activities pursued by suppliers (see, e.g., De Chiara and Iossa, 2019).

PPI instruments Various instruments are available for procuring R&D services or innovative solutions. Unlike standard procurement, where the primary activity is production, innovative procurement involves a preceding R&D phase. PPI instruments can be categorized in several ways, but for the purpose of this paper, it is useful to subdivide them based on whether they cover just one phase—R&D or commercialization—or both. Specifically:

[8] We refer the reader to Nemet (2009) and Costantini et al. (2015) for further discussion and categorization of innovation instruments into push and pull policies.

1. *Unbundled instruments*: These are instruments where the R&D and commercialization phases are separated. Two different procurement processes are implemented, one for each phase.
2. *Bundled instruments*: These are instruments where the R&D and commercialization phases are combined. A single procurement process covers both phases.

In the Appendix, we provide a glossary of the main PPI instruments currently adopted in Europe and the US, categorized according to the classification above. We will refer to the glossary whenever specific PPI instruments are mentioned in the text.

3. Does PPI spur innovation?

R&D public funding other than PPI has been shown to create incentives and generate positive spillovers on the economy, thus mitigating concerns related to the crowding-out effects that may result from government support for innovation (Fleming et al., 2019). Existing research on R&D grants (Azoulay et al., 2019; Santoleri et al., 2024), R&D subsidies (Bronzini and Iachini, 2014), and R&D tax credits (Dechezleprêtre et al., 2023) provides robust empirical evidence that government technology-push policies can encourage innovative private-sector investment. More generally, industrial policies focusing on technology-intensive industries while ensuring competition and accountability for financial support are found to effectively facilitate innovation and technology adoption with persistent benefits both in Western economies (Juhász, 2018; Hanlon, 2019; Cingano et al., 2022; Incoronato and Lattanzio, 2024) and Asia (Aghion et al., 2015; Barwick et al., 2019; Lane, 2021; Bai et al., 2020; Choi and Levchenko, 2021).[9] Promoting private innovation activities directly or indirectly is also the ultimate goal of PPI interventions.

This section focuses on whether and how PPI impacts the innovative performance of firms.[10] Specifically, we examine to what extent winning public procurement contracts encourages firm innovation. By understanding firm-level outcomes, policymakers can gain insights into the micro-level benefits of public procurement contracts, which can then be aggregated to infer broader macro-level effects, such as job creation (Link and Scott, 2012) and productivity growth (Haskel and Wallis, 2013; Moretti et al., 2025). Exploring firm-level effects is also relevant insofar public funding of innovation may differ from private sources in how it impacts the behavior of recipient firms (Clarysse et al., 2009; Gök and Edler, 2012).

In the following, we report empirical findings on the direct effect of PPI as an innovation policy tool from the US and Europe, where nearly all existing studies are focused.[11] We also dedicate separate subsections to green and healthcare procurement as drivers of respectively green and medical innovation, and summarize the sparse evidence on spillover effects.

3.1. Evidence from the US

In the US, PPI instruments such as R&D Procurement (R&DP) and the Small Business Innovation Research (SBIR) program account for about one-third of the $130 billion annual federal R&D budget (de Rassenfosse et al., 2019)—with the remainder distributed among grants and in-house research (Bruce and de Figueiredo, 2020).[12] US federal procurement has been critical to developing some of the most influential technologies of the 20th and 21st centuries, including personal computers, the internet, and GPS systems (Scotchmer, 2004; Ruttan, 2006; Cabral et al., 2006).

Early studies focus on the effects of the SBIR program on firm-level small business performance (Lerner, 2000; Wallsten, 2000). The first quasi-experimental assessment of firm-level innovation outcomes was conducted by Howell (2017), who focuses on the SBIR contests from the Department of Energy (DoE). The DoE runs two-stage contests where winners of the first stage are awarded a small grant and can compete in the second stage for a much larger grant. The study uses a dataset of DoE SBIR applicants and awards from 1983 to 2013. It adopts a regression discontinuity design which compares firms immediately around the first stage award cutoff score, exploiting the fact that the latter is independent of the evaluation process. The author shows that one SBIR award approximately doubles the probability of a firm receiving subsequent venture capital and has large, positive impacts on patenting and revenue. These effects are stronger for more financially constrained firms. The certification level—i.e., the extent to which the selection takes into account information about firm quality—does not explain the effect of the award; instead, the awards are beneficial because by allowing the firm to demonstrate viability with a prototype, they reduce technology uncertainty.

More recently, Howell et al. (2021) examined the implementation of the SBIR program by the Department of Defense (DoD). The SBIR is inherently suitable for defense procurement, which typically involves contracting for both R&D and delivery (Rogerson, 1989). The DoD often considers multiple prototypes before narrowing down the competition and selecting a supplier for delivery (Anton and Yao, 1989; Lyon, 2006). Specifically, the study exploits the “Open” procurement reform of the SBIR adopted by the US Air Force as a quasi-experiment. This reform invited firms to propose innovative technologies with a bottom-up approach. Such an “Open Program” was in contrast with the traditional top-down approach (i.e., the “Conventional Program”), which was narrowly specifying the innovation needs of the buyer. The success of the Open Program is attributed to its bottom-up character: firms were given a chance to present technological opportunities not previously known to the Air Force. The paper exploits administrative data on Air Force SBIR applications and awards from 2017 to 2019, a period during which the two programs were run simultaneously,

[9] See Lane (2020) and Juhász et al. (2024) for a review of this literature.

[10] Evidence on the impact of PPI in comparison and combination with other policy instruments is discussed in Section 6.

[11] An exception is Beraja et al. (2023) who find causal evidence that PPI stimulates firm innovation in China: contracted firms developing AI-based facial recognition technology subsequently innovated more both for the government and commercial markets.

[12] See the Appendix for a detailed description of these and other PPI instruments.

allowing for a meaningful comparison. It employs the same regression discontinuity design as Howell (2017). The findings show that winning an Open award benefited firms in terms of venture capital funding and patenting, while no such benefits resulted from the Conventional program, which was instead found to foster incumbency and lock-in effects. Consistent with Howell (2017), the effect on venture capital is driven by entrants, both in the sense of young firms and those without previous SBIR awards. With the usual caveat that regression discontinuity methods only ensure local validity, these studies provide robust causal evidence that SBIR awards improve the innovative performance of firms, especially young and financially constrained, if they are given the flexibility to explore alternative solutions.

Other studies focus on the effect of PPI on innovative performance at the industry level. Slavtchev and Wiederhold (2016) develop and test a theoretical model, which predicts that a shift in the composition of public purchases toward high-tech products translates into higher economy-wide returns to innovation, thereby raising the aggregate level of private R&D.[13] Their empirical analysis combines data on individual federal procurement contracts from the Federal Procurement Data System (FPDS) with industrial R&D expenditure data from the National Science Foundation for the period 1999-2009. They measure the technological intensity of public procurement as the share of federal procurement in high-tech industries within a given state relative to total federal procurement in that state, considering only non-R&D procurement contracts awarded to private-sector firms. They use fixed effects estimations to investigate the relationship between the technological intensity of public procurement and state-level innovative performance. Their findings indicate that an increase in the technological content of government procurement induces additional private R&D investment in the economy. Additional instrumental variable estimations are provided to support a causal interpretation of the results.

Two more recent studies exploit wartime demand shocks as quasi-experimental settings to estimate the causal effects of PPI on innovation and broader economic performance. Gross and Sampat (2023) focus on the surge in procurement of technologies and medical treatments induced by World War II. They merge contract data from the Office of Scientific Research and Development (OSRD) with postwar patent records and industrial activity measures and use a difference-in-differences identification strategy. Specifically, they compare pre- and post-war patenting outcomes in technology clusters affected by the war procurement shock (treatment group) with those that were not (control group), finding a strong positive effect. Kantor and Whalley (2023) study the effect of the shock of public R&D spending for the space race against Soviet Union in the 1960s on various measures of economic performance. They construct a panel dataset with highly granular data on US manufacturing and NASA contractor activity in large urban counties from 1947 to 1992 and also adopt difference-in-differences methods. By comparing changes in outcomes between space-related industries (treatment group) and other industries (control group) before and after the Space Race, they find an increase in NASA contractors patenting in treated industries, as well as significant but moderate increases in manufacturing value added and employment. Overall these papers provide robust causal evidence that US government's shift in procurement decisions in favor of high-tech sectors influenced the long-term direction of US innovation and had persistent positive effects on the economy.

3.2. Evidence from Europe

The EU has recognized the importance of procurement as a tool for promoting innovation since the early 2000s (Wilkinson et al., 2005), therefore later than the US. In 2014, the EU passed revised procurement directives aimed at facilitating the acquisition of innovations via a number of PPI tools (Iossa et al., 2018).[14] In contrast with the traditional calls for tenders, which left little room for innovative solutions, the newly introduced approach specified procurement needs in terms of functional requirements, took life-cycle cost considerations into account while assessing cost-effectiveness, and defined innovation-related factors as award criteria. This created the necessary preconditions for suppliers to successfully explore and offer innovative solutions at the tender stage.[15] Germany was a forerunner in implementing the revised legal framework, allowing government agencies to specify innovative aspects of procured products as selection criteria in calls for tender. Using Germany as a laboratory, Czarnitzki et al. (2020) study the introduction of this reform on firm innovative performance. They use data from the German section of the European Community Innovation Survey (CIS) – a biannual Eurostat survey on innovation activities across EU firms – for the period 2010-2012. The study employs cross-sectional ordinary least squares (OLS) as the baseline method to assess the effect of winning PPI contracts on innovative performance, finding a significant but modest positive impact. While the baseline analysis does not leverage a quasi experimental setting and thus does not allow for a strict causal interpretation, the authors conduct additional analyses on a subsample that combines survey data with tender-level data from Tender Electronics Daily (TED), an EU procurement tenders dataset. Employing matching, instrumental variable, and difference-in-differences estimations, they address potential endogeneity concerns and support a causal interpretation of their results.

Adopting the same data and methods, Krieger et al. (2024) find that standard procurement tenders - those awarded solely based on price - negatively affect the innovative performance of firms. Winning standard tenders reduces firms' product and process innovations while increasing their focus on their established products and services. This suggests that non-innovative procurement, which still represents the large majority of all tenders, is not neutral but detrimental to the innovative performance of firms.

Also based on firm-level CIS survey data, Stojčić et al. (2020) examine the impact of PPI on innovation and output across eight Central and Eastern European countries from 2012 to 2014. The paper adopts matching techniques to compare outcomes between

[13] Their growth model is based on Cozzi and Impullitti (2010), which shows that an increase in the technological content of public spending increases the wage skill premium, R&D, and human capital accumulation.

[14] See the Appendix for a description of these tools.

[15] See Directive 2014/24/EU, par. 74.

firms receiving PPI contracts and those that do not.[16] The study finds that PPI positively influences both innovation and output, with the strongest effects occurring when firms combine PPI contracts with other forms of public support. This highlights the potential of tailored policy mixes to stimulate innovation, particularly in catching-up economies (see Section 6). In both Czarnitzki et al. (2020) and Stojčić et al. (2020), the induced innovations are primarily incremental, suggesting that PPI could be more effective in stimulating technology diffusion rather than breakthrough innovation.

To conclude, the existing evidence overall indicates that PPI in the EU has so far had a positive but moderate effect on innovation. It should be noted that these studies rely on survey data, which are prone to potential selection bias. An additional limitation specific to the CIS survey is that it provides only binary information on whether awarded contracts were of an innovative nature. Given these caveats, further research – particularly using tender-level data – is needed.

3.3. Green procurement and green innovation

The green transition requires the development and widespread adoption of green innovations. Such investments are prone to a combination of market failures, particularly environmental externalities and technology spillovers, making the theoretical case for green industrial policy quite strong (Rodrik, 2014; Van Reenen, 2023). While market-based environmental policies—such as carbon pricing or taxes—are crucial, they need to be complemented, at least in the short term, by industrial policies to create incentives at a sufficient scale to overcome the inertia and accelerate the transition (Acemoglu et al., 2012, 2016; Van Reenen, 2023). By creating demand and lead markets for green products, green procurement appears to have potential to contribute towards this objective. This potential market-pull role is especially relevant in sectors with a large environmental impact and where public authorities command substantial market shares, such as defense, health, construction, and transportation (see, e.g., Hertwich and Peters, 2009 and Wiedmann and Barrett, 2011).[17]

The empirical literature highlights demand as one of the main drivers of environmental innovations (e.g., Horbach et al., 2012; Kesidou and Demirel, 2012; Veugelers, 2012; Costantini et al., 2015, 2017). A set of studies focuses specifically on innovative green public procurement (IGPP) as a stimulus for the development of eco-innovations. For instance, Ghisetti (2017) studies the role of IGPP in driving the adoption and diffusion of sustainable manufacturing technologies. Using data from the 2015 EU Innobarometer survey covering manufacturing firms in the EU, Switzerland, and the US, and employing non-parametric matching estimation techniques, the study finds that winning IGPP contracts increases a firm's probability of adopting sustainable manufacturing technology within 12 months. Orsatti et al. (2020) provides additional descriptive evidence, finding a positive relationship between IGPP spending and green patent activity at the US Commuting Zone level.

Krieger and Zipperer (2022) investigate the effect of winning IGPP contracts on firms' probability of introducing novel and more environmentally friendly products and processes. They merge firm-level data on environmental innovation activity from the 2009 and 2015 waves of the German CIS survey with tender-level data from TED (2006-2015). By analyzing award criteria in procurement documents, they classify awards as green and not green and employ a cross-sectional difference-in-differences method to identify the effect of green awards on firms' environmental innovation performance. Their findings indicate that IGPP has a positive impact, primarily on product, rather than process innovation, with the effect being driven by small firms. In contrast, no significant effect is found for larger firms, aligning with the idea that firms facing greater financial constraints might be more responsive to innovation policies (Dechezleprêtre et al., 2023; Santoleri et al., 2024). Focusing on a large US affirmative procurement program for sustainable products, Chiappinelli et al. (2025) provide causal evidence on the effects of winning green contracts on the environmental and economic performance of contractors. They combine federal procurement data (FPDS) with firm-level emission and balance sheet data of publicly traded firms (Refinitiv) from 2007 to 2019. Using staggered difference-in-differences, they find that securing green contracts reduces emissions relative to firm size and increases productivity, with these effects persisting in the long run. The effects are stronger for smaller firms, those for which green procurement is more critical to their business, and those less innovative. Innovation is identified as a key mechanism behind environmental and economic improvements. In addition, the authors find no evidence that the program crowds out private sales.

In conclusion, while quasi-experimental evidence on green procurement as a driver of green innovation is still scarce, existing studies appear to provide robust evidence of a positive effect, particularly for small firms.

3.4. Healthcare procurement and medical innovation

Market and demand size have been shown to be important drivers of innovation in the healthcare sector (Acemoglu and Linn, 2004; Blume-Kohout and Sood, 2013; Dubois et al., 2015). However, the literature on the specific role of public demand, and more specifically public procurement, is scarcer. Toole (2012) investigates the impact of publicly funded medical research on pharmaceutical innovation. The study exploits data on grant and contract awards from the US National Institutes of Health (NIH) combined with pharmaceutical industry R&D investment data. The main finding is that NIH-funded basic research is associated with increased entry of new drugs, with the largest contribution coming in the early stage of drug discovery. However, the study does not distinguish between contracts and grants, making it difficult to isolate the specific effect of PPI, nor does it adopt a quasi-experimental approach, so the results cannot be interpreted causally.

[16] The authors acknowledge the possibility that unobserved differences between treatment and control groups may introduce selection bias, limiting the causal interpretation of their findings.

[17] Government consumption alone is responsible for 10% of carbon footprint globally (Hertwich and Peters, 2009).

A few studies have focused specifically on vaccines. Finkelstein (2004) exploits policy changes in the 1990s that increased public demand for vaccines in the US as a quasi-experimental setting to investigate the causal effect on medical innovation. This can be viewed as a public procurement demand shock, since vaccination in the US is largely covered by public programs. The study finds robust evidence of a significant increase in new vaccine clinical trials for diseases affected by the policies, compared to a control group of unaffected diseases. Agarwal and Gaule (2022) investigate the relationship between market size and R&D effort using a cross-section of worldwide medical trials from 2015 to 2019. Their descriptive evidence reveals a positive correlation and suggests that the surge in public demand for vaccines and medical devices triggered by the COVID-19 crisis will likely accelerate related R&D efforts beyond what historical trends would predict. They also find suggestive evidence that US vaccines moved faster to preclinical stages and were more likely to enter clinical trials because of the incentives provided by the advance purchase contracts signed by the US government for various vaccine candidates to facilitate and accelerate vaccine development, manufacturing and distribution (see Subsection 4.3).

Clemens and Rogers (2023) study the effect of medical procurement demand shocks, specifically related to prosthetic devices, during the US Civil War and World War I (WWI) on medical innovation activities and the role of contract design. They construct a dataset of prosthetic patenting which includes information on production process and quality. Using difference-in-differences methods, they compare patenting activities related to prosthetic technologies (treatment group) to patenting in other technologies (control group) before and after the wars. They find that patenting volumes were larger for prosthetics in both wars. Additionally, during the Civil War, patents focused on cost-reduction, while during WWI, they focused on quality. These patterns reflect that different procurement priorities and approaches create different incentives: during the Civil War the priority was cost containment, which created incentives for cost-reducing innovation, while during WWI the priority was the social reintegration of veterans, which created incentives for quality-enhancing innovation.

Despite the variety in terms of applications and methods, the evidence reviewed consistently indicates that public demand is an important driver of medical innovation, and that procurement design features likely play a key role in shaping innovation incentives.

3.5. Spillovers

We conclude this section with a discussion of the recent yet sparse literature on PPI spillover effects. Understanding the impact of PPI spillovers is relevant because, if PPI affects technologically close peer firms, this could imply even more significant underinvestment in R&D than traditionally hypothesized.[18] This literature reports cross-country and within-country spillovers. Evidence on cross-country spillovers is limited to Moretti et al. (2025), which examines the impact of US government defense R&DP spending on private R&D activity. The study conducts both an industry-country-level analysis using OECD data (1987–2009) and a firm-level analysis using French data (1980–2015). To address the potential endogeneity of government fund allocation, the authors employ instrumental variable estimations. Their findings reveal positive international spillovers: increases in government-funded R&D in a particular industry and country lead to higher private R&D in the same industry in other countries. While no innovation effect from domestic push policies abroad is detected, substantive innovation spillovers arise from domestic pull policies. This suggests that demand-pull policies might need to be coordinated at a supranational level to internalize the spillovers.

Evidence on within-country spillovers is relatively more abundant and generally supports positive effects (i.e., crowding-in), aligning with theoretical predictions. The results in Slavtchev and Wiederhold (2016), as discussed in Subsection 3.1, indicate that an increase in the technological content of government procurement induces additional private R&D investment in the economy. Similarly, Moretti et al. (2025) finds that government-funded R&D targeted at specific industries results in significant increases in private sector R&D within those industries. Kantor and Whalley (2023) assess whether technologies discovered by NASA contractors during the Space Race spilled over to neighboring firms, enhacing local productivity. However, they do not detect such local technological spillovers.

While the literature is still too sparse to draw general assessments, existing evidence appears to indicate that PPI can generate positive spillovers.

4. How should PPI be designed to best spur innovation?

The previous section reviewed the empirical, mostly micro-level, evidence on the degree to which PPI successfully encourages innovation. This section, by contrast, has a normative purpose. In summarizing the relevant state of the art, we aim to shed light on *how* PPI should be designed to improve its performance as an innovation lever. Recent work on industrial policy highlights the importance of policy design to ensure effectiveness while accounting for potential market distortions (Kalouptsidi, 2018; Barwick et al., 2019; Itskhoki and Moll, 2019; Liu, 2019). We discuss various design dimensions and the trade-offs they entail. We conclude the section with dedicated discussions on the design of green and new-vaccines procurement.

4.1. The complexity of PPI design

There are several layers of complexity that PPI adds to standard procurement, which need to be considered for effective policy design. First, unlike standard procurement, where the primary focus is on production, and the main regulatory concern is cost

[18] For instance, in the context of R&D grants, sectoral spillovers are channeled in the form of higher rates of entry into entrepreneurship (Santoleri et al., 2024).

efficiency, innovative procurement includes a R&D phase before the production phase. Therefore, the procurement process should also aim to create incentives for the company to exert innovative effort, which may, to some extent, conflict with the goal of cost efficiency. Second, the difficulty in observing and verifying innovation efforts introduces information asymmetries between buyer and seller, adding to the standard informational asymmetries related to production costs. Third, the fact that the innovation might have value only for the buyer poses a risk that the seller may be (partially) expropriated of the surplus it generates through R&D, creating a "hold-up problem". This further affects the provision of innovative efforts. Combined with uncertainties inherent to innovation, these issues shape PPI as a multi-faceted incentive problem. This complexity requires contracts and procedures to be designed in a manner that provides suppliers with the right incentives to meet the objectives of innovation performance and efficiency. Several design dimensions are relevant in this context.

Bundling versus unbundling The incentives for innovation suppliers can be significantly affected by whether the procurement design is bundled or unbundled. This issue was first investigated in the context of military and defense procurement, where bundling is common. Rogerson (1989) provides a first theoretical analysis suggesting that since innovation quality is difficult to describe or measure objectively, regulatory instruments should be designed to create incentives for innovation in the form of positive profits on the production contract.[19] These results provide a rationale for why defense procurement is typically bundled with sole-source production.[20] In a follow-up work, Rogerson (1994), the author further argues that multi-year contracts in such settings do not only enhance innovative efforts by addressing the hold-up problem, but also amplify cost efficiency incentives by expanding the regulatory lag.

Che et al. (2021) add granularity by considering specific conditions under which bundling is more beneficial than unbundling. The authors study the incentive problems arising both ex-ante, at the innovation stage, and ex-post, at the contract implementation phase. To do so, they employ a contract-theory model with both moral hazard - the innovator's effort is unverifiable and stochastically increases the value of the innovation - and adverse selection - suppliers have private information on their cost of implementing the contract. They show that, in case of exclusive development (i.e., when the innovation is valuable only to the buyer), the mechanism should accord preferential treatment to the proposer of a highly innovative solution. Such preferential treatment takes the form of a follow-on contract for the implementation of the proposed solution (e.g., supply of commercial products) that is bundled with the initial development stage, provided the innovation is sufficiently valuable for the public buyer. To fulfill its incentive purpose, the value of the follow-on contract should increase with the value of the proposed solution for the buyer.

While the aforementioned studies suggest that bundled approaches could align with economic principles on the optimal procurement mechanism to incentivize innovation, there are a number of counter-arguments suggesting that this is not necessarily the case. A prominent issue with bundled approaches is the risk of setting an excessive price for the follow-on contract. This can occur when innovations are not sufficiently valuable for the buyer, are already available in the market, or when proper competition amongst potential suppliers is lacking. While the risk of distortions to competition may also arise under unbundled procedures, the peculiarity of bundling—where a follow-on contract is awarded to the supplier of R&D services—exposes this procedure to a greater risk. The uncertainty at the tendering stage regarding production, combined with the discretion in selecting contractors, may impede the setting of a price that could be considered a 'market price' (Arrowsmith, 2010). As a result, the contracting authority may end up paying an excessive price for the commercialized product, and there may be market foreclosure of entrants that are unable to sell to the contracting authority that is locked into the follow-on contract.

Acknowledging these issues in a non-technical discussion, Iossa et al. (2018) concludes that the suitability of bundled procurement depends on various factors, including the specific nature of the innovation, the verifiability of research efforts, and the information asymmetry between buyer and contractor. The benefit of bundling is more likely to outweigh its costs when i) there are significant economies of scope between the two phases; ii) the innovation is public-sector specific, i.e., highly valuable for the public buyer but without significant demand from the private sector; iii) there is no significant risk of market foreclosure and supplier lock-in; iv) there are strong institutional incentives within the procurer organization, ensuring that low-value projects are not continued; and v) project value is observable and measurable ex-post (i.e., informational asymmetries are low).

Decision rights allocation Another mechanism that can be harnessed to incentivize innovative efforts from suppliers is the allocation of decision rights between the buyer and the seller. Contract theory predicts that when quality or effort is not contractible, a higher degree of government involvement or decision rights improves performance. However, this requires government personnel to have adequate expertise and incentives (Hart et al., 1997; Williamson, 1999). Bruce et al. (2019) find evidence supporting these predictions in the context of PPI. They combine US administrative data on government research grants and cooperative agreements with patenting data and information on US civil servants from 2000 to 2011. Using instrumental variable methods they show that cooperative agreements are more likely to perform better in terms of innovative output relative to standard grants because they allow for higher buyer discretion. This is particularly true for early-stage projects, where uncertainty is higher, and when government personnel have the necessary expertise.

[19] Another issue studied by this early literature is the trade-off between quantity and quality in defense procurement, motivated by the observation that often in defense procurement there is a tendency to purchase an excessive number of high-quality weapons (see, e.g., Rogerson, 1995, Feinerman and Lipow, 2001). McKean (1964) was the first to document the defense's apparent bias toward "too much quality" in a long series of examples.

[20] For example, in the approach of the US DoD, while competition among different designs in the R&D phase is allowed—and two design approaches are funded until the development stage—the production is sourced from a single firm (at least initially).

Award criteria The economic literature suggests that to incentivize innovation from suppliers, the procurer should base the requirements and award criteria on the output or functionalities that the contractor must provide, rather than prescribing the adoption of specific inputs or technologies. This approach allows the supplier to explore innovative solutions (see, e.g., Cabral et al., 2006, Edquist and Zabala-Iturriagagoitia, 2020). However, Fabra and Montero (2022) highlight that this flexibility might come at a cost. In a standard private-values auction setting where the regulator has to procure multiple units of a good (e.g., green energy) produced using different technologies with varying costs, the authors investigate whether the procurement award mechanism should be technology-specific or technology-neutral. They find that the optimal choice involves the standard trade-off between cost efficiency and rent extraction. On the one hand, allowing technologies to compete in a technology-neutral mechanism favors cost efficiency, as it allows allocating production to the more efficient technology. However, it comes with the risk of overcompensating efficient suppliers, therefore scoring low on rent extraction. On the other hand, running two technology-specific mechanisms allows reducing rent payments yet at the cost of an efficiency loss. Therefore, while a technology-neutral approach might favor the exploration of innovative solutions, this can come at the cost of excessive rents left to suppliers.

An additional point is that innovative technologies evolve and exploit learning effects over time. This dynamics needs to be considered at the award stage. Specifically, there is a relevant trade-off between sustaining a short-term extra cost in terms of efficiency loss and a long-term one in terms of lock-in risk. Favoring a long experimentation phase by supporting lagging technologies with higher costs might be preferable if the technology's life cycle is expected to be relatively long, making the cost of ending up with the wrong standard relatively high (Cabral et al., 2006). This approach is also beneficial when the potential for technology improvement is significant enough (Cabral and Kretschmer, 2004).

Award procedure The design choice also involves the award procedure format. A central question is whether the contract should be awarded via an auction or via a negotiation. The theoretical and empirical literature on standard procurement (Bajari and Tadelis, 2001; Bajari et al., 2008, 2014) posits that underlying this choice is a trade-off between promoting price competition and transparency ex-ante, at the contract award stage, and reducing costly renegotiations ex-post, at the contract execution stage. This trade-off depends on the complexity of the project and on the extent of information asymmetries between the contracting parties. Auctions can spur price competition but require a complete specification of the contract object, which can be very difficult and costly to provide ex-ante. This can lead to costly renegotiation ex-post, also driven by potential opportunistic behavior from suppliers who are usually at an informational advantage. On the other hand, negotiations allow interaction with a better-informed supplier, thereby reducing the scope for renegotiation, yet at a potential cost in terms of competition and transparency loss. Auctions—often in combination with fixed-price contracts—have been shown to perform best for the award of standardized and well-defined products where the priority is to prompt price competition. On the other hand, negotiations—often in combination with cost-plus contracts—are superior for technically, legally, or financially complex projects for which the ex-ante description is potentially incomplete, and where, as a result, the priority is to reduce the risk of costly ex-post renegotiations.

In PPI, contracts are often also awarded through contest mechanisms. Typically, as in the case of the SBIR program, multiple potential suppliers conduct costly research to develop innovative products, and the procurer offers one of these firms a delivery contract as a prize. Factors such as the value of the procurement contract, the number of contestants (at each R&D phase), and their characteristics (i.e., the value of their innovation and their cost efficiency) determine the level and structure of competition, which in turn influences incentives to exert effort. Bhattacharya (2021) develops a structural multi-stage contest model based on the US DoD SBIR program. The study uses federal procurement data (FPDS) and Navy award data to estimate the primitives of R&D contests and evaluate the trade-offs associated with these factors. For example, a higher contract value can exacerbate a firm's incentive to displace competitors from subsequent stages (i.e., *business stealing* effect) because firms have a greater incentive to compete for the award, leading to the overprovision of innovative efforts. This can more than offset the underprovision of effort due to the holdup effect. In addition, increasing the number of competitors is directly beneficial when R&D outcomes are highly uncertain, despite the cost of effort duplication. The benefit of increasing competition in the presence of uncertainty can outweigh the cost of reducing incentives to unilaterally exert effort due to a lower probability of winning. The author concludes that inviting more contestants in a setting with symmetric bidders (i.e., small companies, start-ups, entrants) can increase welfare at the margin. This result diverges from other contest-theory studies, which argue that given the negative impact of larger participation on effort provision, it might be optimal to restrict entry and extract surplus by charging contestants an entry fee (see, e.g., Taylor, 1995, Fullerton and McAfee, 1999, Che and Gale, 2003). In the case of asymmetric contestants, handicapping the most efficient contestant and allowing for multiple prizes can boost contestants' performance (see, e.g., Che and Gale, 2003 and Cabral et al., 2006).

Centralization Another relevant design dimension is the degree of procurement centralization. This decision involves a trade-off between efficiency and responsiveness to local preferences. On the one hand, centralization of purchases allows suppliers to exploit economies of scale, resulting in potential savings for the procurer in terms of both purchase and process costs. It also facilitates product standardization and concentration of skilled human resources. On the other hand, decentralization allows for greater variety and flexibility, thereby responding better to specific local needs (see, e.g., Dimitri et al., 2006). Existing empirical evidence appears to support the case for more centralized purchasing (Bandiera et al., 2009; Castellani et al., 2018; Bucciol et al., 2020; Chiappinelli, 2020; Clark et al., 2021; Lotti et al., 2024; Wang and Zahur, 2022). In the context of PPI, demand size and scale effects are crucial, making the case for centralization particularly strong. Market and demand size have been shown to be important drivers of innovation (Blume-Kohout and Sood, 2013; Dubois et al., 2015; Acemoglu and Linn, 2004; Aghion et al., 2024). As discussed in Section 3, a few recent studies examine the role of demand size in the specific case of PPI. For example, Clemens and Rogers (2023) show that the demand shock created by wartime public procurement of prosthetic devices led to a substantial increase in innovation in the

sector. Agarwal and Gaule (2022) find that the surge in public demand for vaccines and medical devices driven by the COVID-19 crisis accelerated related R&D efforts beyond what historical trends would predict. These results suggest that, by boosting demand size, joint procurement and centralization have the potential to expand the power of PPI as an innovation trigger. Ahuja et al. (2021) discuss the benefits of such demand aggregation strategies specifically in the context of vaccine procurement.[21] Aggregation can leverage monopsony power to contain prices, coordinate vaccine supply, exploit economies of scale in contracting, planning, and supply chain investment, as well as facilitate efficient priority setting. Similar joint procurement and demand aggregation strategies could also be explored and leveraged in other critical areas such as defense, energy, and critical materials (Draghi, 2024; Piechucka et al., 2024).[22]

4.2. The optimal design of green procurement

Research on the design of procurement of green technologies is at its infancy. Chiappinelli and Seres (2024) provide an auction theoretical study of a preferential green procurement program based on a bid discount, showing that it creates incentives for sufficiently efficient brown suppliers to invest in green technology. This work suggests that green procurement programs may create incentives for companies without distorting competition in favor of less efficient firms – a frequent criticism against other preferential programs. The paper also shows that such a discount-based mechanism is analogous to a standard scoring rule where the procurer gives a weight to both price and green quality as studied by Asker and Cantillon (2008, 2010) and that, if augmented with a reserve price, the mechanism can be optimal for a procurer who cares about minimizing the purchasing price while triggering green investment.

Some additional insights on green procurement design can be drawn from the above discussion of the literature on award criteria and procedures. First, the analysis on optimal procurement in the presence of multiple technologies by Fabra and Montero (2022) directly applies to the procurement of green technologies. For example, when procuring renewable energy production, the procurer can choose between a number of technologies (e.g., solar and wind) which differ in their costs. The results of the paper suggest that for a procurer that is imperfectly informed about relative technology costs and cares about minimizing costs for society, the choice between technology-neutral and technology-specific award procedures has to be taken case by case depending on the characteristics of the technology and on the degree of information asymmetry. Second, the lessons on the relative advantages of negotiations and auctions can be applied to the procurement of innovative decarbonization technologies (e.g., low-carbon material manufacturing) where there is ex-ante uncertainty about the ex-post performance.[23]

4.3. The optimal design of new-vaccines procurement

A strand of works studies the optimal design of new-vaccine procurement, for example via Advance Purchase Agreements or Advance Market Commitments (see, e.g., Kremer and Glennerster, 2004; Berndt and Hurvitz, 2005; Glennerster et al., 2006; Berndt et al., 2007; Turner, 2016; Kremer et al., 2020).[24] Within this strand of the literature, some studies specifically consider COVID-19 vaccines (Snyder et al., 2020; Ahuja et al., 2021; Kremer et al., 2022; Dewatripont, 2022).

The main emphasis in this context is on the hold-up problem that arises because buyers in ex-post negotiations can appropriate returns from the pharmaceutical firm's sunk investment in vaccine production capacity. Kremer et al. (2022) formalize these issues in a multi-stage game between a purchaser that can offer different types of contracts and a firm that must invest in both R&D and capacity. After the investments are sunk, the firm bargains with the buyer about future vaccine purchases. The study finds that the optimal contract design varies significantly depending on how far in the R&D process the new-vaccine production is. If the new vaccine is in the early stage of R&D, the priority is to spur investment in R&D rather than in capacity. In this case, a framework design that subsidizes initial purchases using a fixed payment is appropriate. On the other hand, if the vaccine is in the late stages of R&D, the priority is to spur investment in capacity. In this case, a supply commitment or a capacity-forcing agreement that limits the firm's discretion over capacity can create the right incentives.

A related issue is the risk for pharmaceutical companies to invest in capacity that eventually proves worthless, leading to postponing investments in large-scale capacity until the vaccine has been proven effective and gained market authorization. However, this delay might be very costly for society in cases in which the need for vaccine deployment is very urgent. For example, as the COVID-19 crisis demonstrated, the pressure at the outset of an epidemic or pandemic requires vaccines to be produced and distributed as soon as they are approved. Motivated by these considerations, Ahuja et al. (2021) assess contractual options to accelerate investments in capacity. They analyze a model where the buyer invests in vaccine candidates "at risk," that is, in parallel with clinical trials and compare push and pull procurement contracts. On the one hand, with push contracts, the buyer reimburses the supplier's installation costs before testing and regulatory approval are complete, thereby assuming all the risk. On the other hand, with pull contracts, the buyer commits to purchasing vaccines on specified terms, but only if regulatory approval is successful, shifting the risk to suppliers.

[21] For example, in response to the Covid-19 pandemic, the European Commission negotiated advance purchase agreements with vaccine manufacturers on behalf of Member States.

[22] Aggregation of demand has for example proven valuable in the context of the gas crisis ensuing the Ukraine war through AggregateEU, an EU mechanism which enabled joint gas purchasing at the European level. Additionally, the establishment of a Critical Raw Material Platform is currently under discussion.

[23] See the Appendix for a detailed description of instruments for the procurement of innovative decarbonization technologies, such as Carbon Contracts for Difference (CCfDs). These instruments are currently at the policy design stage, for example in the EU (see e.g., Draghi, 2024 and Piechucka et al., 2024).

[24] See the Appendix for a description of these instruments.

The authors conclude that when suppliers have private information on the probability of success, procurers should contract directly on capacity, relying primarily on demand-pull schemes. At the same time, a technology-push component can be added to incentivize speed.[25] The rationale for this mechanism is that when firms have private information on the probability of success, pull contracts are expensive relative to push contracts, as inducing risky investments from a diverse set of firms requires offering all firms a price high enough to induce the marginal firm to invest. This leaves substantial rents for firms with a high probability of success.

5. What barriers hinder the implementation of PPI?

In this section, we review the sparse scholarship on the barriers to PPI implementation. The existing literature is empirical and focuses on buyer capabilities as a major factor influencing PPI performance. This is relevant as successful industrial policy design and implementation are shown to rely on bottom-up rather than top-down approaches and on collaboration between governments and firms, thereby highlighting the importance of governance quality (Juhász et al., 2024).

5.1. The pivotal role of the buyer in PPI

Numerous frictions may arise in PPI on both the supplier and buyer side, limiting the ability of suppliers to innovate and of buyers to benefit from innovative outcomes. For instance, Georghiou et al. (2014) presents a comprehensive taxonomy of procurement instruments that have emerged in OECD countries in response to perceived shortcomings and then compares them to business perceptions based on a dedicated survey of 800 public sector suppliers in the United Kingdom. The survey finds that companies face barriers originating from the buyer's failure to consider the full procurement cycle and risk aversion. Therefore, excluding financial constraints, the main remaining barriers reported by suppliers relate directly or indirectly to the buyer side. Uyarra et al. (2014) corroborates these findings, highlighting that the lack of interaction with procuring organizations, use of over-specified tenders as opposed to outcome-based approaches, insufficient skill on the part of procurers, lack of useful feedback and communication, and poor risk management during the procurement process are examples of the main barriers reported by suppliers. These frictions are perceived as even greater when the supplier is a small company or nonprofit organization.

Empirical evidence on standard procurement in different sectors and contexts has indeed shown that buyers have a significant impact on contract performance and can explain a relevant share of variation in outcomes (Decarolis et al., 2020; Bucciol et al., 2020; Baltrunaite et al., 2023; Best et al., 2023).[26] In PPI, public buyers are likely to play an even more critical role in project success than in standard procurement because of its higher complexity.[27] Causal evidence on the relevance of the buyer side in the context of PPI was first provided by Bruce et al. (2019) and Decarolis et al. (2021), with a focus on the US. As already mentioned in the previous section, the former study finds that discretional cooperation agreements are particularly effective in fostering innovation when procurement officials are more competent. The latter study provides the first quantification of the role of public buyers in R&DP success. Specifically, the authors combine US federal procurement data (FPDS) with a database on federally funded patents (3PFL) from 2006 to 2012 and leverage variations in manager deaths across contracting agencies and time to causally estimate the probability that contracts deliver patented inventions. Manager deaths are found to have a strong, negative impact on project innovation outcomes, as measured in terms of patents plus their citations and claims. These results suggest that the death of managers leads to a disruption in specialized human capital that is difficult to replace. The study also discusses the possible mechanisms behind the buyer's role. By using data on federal public workforce characteristics and their perception of the work environment, the authors find that better work environments do not compensate for the sudden loss of specialized human capital through higher levels of perceived office cooperation, skills, or incentives. To further explore channels through which buyers may impact innovation, Giuffrida and Raiteri (2021) spotlight the most disaggregated decision-maker, the official responsible for the procurement process—commonly referred to as the contracting officer in the US. The authors focus specifically on (excessive) bureaucratic workload as a capacity bottleneck for officers in PPI units. Using the same procurement and patenting data as the previous study (with a focus on Air Force contracts), complemented with records on contracting officers, the authors aim to identify the effect of buyer's workload on contract-induced innovation. By leveraging unexpected retirement postponements among contracting personnel as an instrumental variable, the authors show that when an officer's workload decreases, there is a sharp increase in patenting. They find that officer workload is more disruptive at the margin when the time available to complete the transaction is less, leading to poorer guidance embedded in the contract. Suppliers that suffer from high buyer workloads are those that need the most guidance—that is, small and inexperienced firms. Consequently, the negative impact of bureaucratic workload is most relevant in cases in which the role of procurement personnel is central to the R&D process. While research is still very limited, the existing evidence consistently indicates that the lack of capabilities of procurement personnel as well as the time and resource constraints in procurement offices are important barriers for PPI-induced innovative performance.

[25] The push payments should, however, cover less than the entire cost, giving firms "skin in the game" and deterring those with no realistic chance of success from accepting push funding.

[26] Saussier and Tirole (2015) report that in the majority of OECD countries the occupation of public buyer is not specifically recognized and that often public officials lack the appropriate capabilities and expertise. Based on a survey of French procurers, they report that often officials join the purchasing department as a result of internal mobility with no prior experience in the field and without receiving specific training on purchasing activities. They argue that this lack of professionalization and competences is an important barrier for efficient procurement implementation in general.

[27] The role of buyer capabilities, motivation, and organizational incentives are often mentioned also as essential drivers for implementation of green public procurement, another form of complex procurement (see, e.g., Brammer and Walker, 2011, Grandia, 2015, Testa et al., 2016).

6. What is the role of PPI in the innovation policy mix?

PPI is only one of various policy instruments available to incentivize innovation. Therefore, it is relevant to ask how PPI performs relative to other instruments and how it might be combined with them to maximize incentives for innovation. This is particularly important as successful industrial and innovation policy relies on a careful combination of different instruments beyond stand-alone subsidies (Acemoglu et al., 2012, 2016; Juhász et al., 2024). This section presents the existing research on the theoretical and empirical assessment of the relative performance of PPI compared to and in combination with other innovation policy tools.

6.1. The relative performance of PPI vis-à-vis alternative policies

Mixing different innovation policies generates the risk that firms may benefit simultaneously from several policy instruments, potentially creating a culture of dependence on the public sector and decreasing the effectiveness of innovation policy expenditures. Additionally, if the combination of innovation policies implemented by different government agencies is not well coordinated, public intervention in market activities may result in an inefficient use of resources, potentially leading to policy failure (Link and Link, 2009). A rich body of (primarily empirical) literature studies the determinants of innovation, highlighting the importance and role of demand-pull factors relative to and in combination with technology-push ones (see, e.g., Horbach et al., 2012 and Veugelers, 2012). This literature also emphasizes the importance of a balanced, comprehensive, and consistent policy mix (see, e.g., Costantini et al., 2015 and Costantini et al., 2017). However, few studies explicitly address the role and relative performance of procurement as part of a broad policy framework to stimulate innovation.

To our knowledge, De Chiara and Iossa (2019) provide one of the few theoretical analyses of the relative performance of PPI versus other instruments. They compare PPI and R&D grants in a model of project competition where the firm has superior information on which projects are available and where the preferences of the authority and the firm are misaligned—i.e., the most socially valuable projects are the least profitable. The authors find that both procurement and grants create incentives for investment that would not have been carried out without public intervention. However, there is a trade-off. On the one hand, grants create a crowding-out effect—i.e., induce firms to substitute private with public funds to finance their preferred projects—which is socially inefficient when there is a cost of public funds. On the other hand, PPI creates a steering effect—i.e., induces firms to redirect their investment toward projects aligned with the preferences of the authority—even when it is socially inefficient to do so ("picking the wrong winner"). The authors conclude that procurement is preferable to grants when the projects preferred by the authority are highly socially valuable but of limited profitability (i.e., when the cost of "picking the wrong winner" is low) and when public funds are costly (i.e., when the cost of crowding out is high).

Cabral et al. (2006) conceptually assess the relative performance of PPI versus intellectual property. They argue that this issue boils down to comparing the distortions created by the two mechanisms. On the one hand, in PPI, asymmetric information on the value of innovation makes it difficult to choose the correct level of the contract value. Therefore, some innovations are overincentivized while others are underincentivized. On the other hand, a patent system creates the distortion associated with monopoly pricing. The authors conclude that procuring innovations through PPI tends to be preferable to intellectual property when the innovation is easily describable in advance, the expected costs of monopoly prices are high, the occurrence of the innovation is verifiable, and there is little informational asymmetry on the value of the innovation. However, as far as we know, no research has explored whether and how to optimally combine PPI and patent protection. This is particularly relevant for unbundled approaches, where the innovator cannot be compensated with production rights. In this case, the government could decide to just award a prize to the innovator while retaining exclusive rights to the innovation or making it public. Alternatively, the procurer could decide to remunerate the innovator with some degree of property rights.[28] In either case, the procurer should carefully take into account these considerations when designing the compensation for the innovator.

Based on CIS survey data for a broad sample of firms in Germany between 2000 and 2002, Aschhoff and Sofka (2009) provide an empirical analysis to compare PPI to three other innovation policy instruments, namely public co-funding for private innovation, knowledge spillovers from publicly funded universities, and intervention through regulation (e.g., quality standards). Using Tobit regressions, they find that public procurement has a positive and significant effect on the innovative performance of firms—measured by the market success of their innovations—similar to knowledge spillovers from universities. On the other hand, neither regulation nor public funding for innovation seems to significantly impact market success. Procurement appears to have a more pronounced impact on smaller firms located in economically distressed regions. This aligns with findings from Stojčić et al. (2020), who observed that PPI has a greater effect on firms located in emerging economies. However, these results can only be interpreted as correlations and not as causal.

Based on data from the EU Innobarometer survey for the period 2006-2008 and using propensity score matching techniques, Guerzoni and Raiteri (2015) provide an empirical assessment of PPI versus two supply-side policies i.e., R&D subsidies and tax credits. The authors find that when the interactions between different policies are accounted for, the effect of R&D subsidies is no longer significant, and the effect of tax credits is much weaker than when not controlling for policy interactions. In contrast, the positive effect of PPI persists. These results suggest that PPI might dominate supply-side policies when used in isolation. However, the authors also highlight that there are synergies between the instruments, indicating that a policy mix can have a greater impact than either instrument on its own. Under the caveat of the limitations of survey data, these results appear to be robust.

[28] Such sharing agreements are, for example, those envisaged by the EU's Pre-Commercial Procurement procedure. See the Appendix for more details on this instrument.

As already mentioned in Section 3, Stojčić et al. (2020) reveal the beneficial effects of both financial support and PPI in Central and Eastern Europe. Their analysis shows that, when considered in isolation, PPI can be more effective than financial support, particularly when it is designed to stimulate innovations that are new to the market, rather than mere imitations that are only new to the firm. In this circumstance, the combination of both instruments proves to be more effective than either one used alone. However, the opposite is true when PPI is structured to induce innovations that are beneficial solely to firms, without being new to the market. In this scenario, the push channel alone dominates, and the bundling of instruments is less effective than using each policy in isolation. In a related study also based on CIS survey data for the period 2010-2014 and matching techniques Caravella and Crespi (2021) find similar evidence for the Italian manufacturing sector.

Czarnitzki and Prüfer (2024) empirically investigate the effect of PPI, R&D grants and their interplay on R&D investment for a sample of Belgian firms. They create a panel database by combining five waves of the Flemish leg of the CIS survey from 2013 to 2021 and adopt difference-in-differences estimation methods. Similarly to the previous papers, they find causal evidence that both PPI contracts and R&D grants have positive effects on firms' R&D investment. However, they challenge the previous evidence insofar they find that the combined implementation of the instruments induces substantial crowding-out effects. The panel nature of their data allows the authors to control for unobserved heterogeneity among treated and control firms, a limitation faced by the previous studies that relied on cross-sectional data. While still prone to the limitation of (CIS) survey data, this paper appears to provide the most robust causal evidence.

Therefore, while the literature remains overall inconclusive, it suggests that failing to carefully consider interactions between policy instruments may reduce the effectiveness of innovation policy packages. In addition, it is important to note that the efficiency of both R&D grants and PPI, as individual instruments or in combination, crucially depends on the ability of the granting or contracting authority to measure expected spillovers and tailor grant and contract design accordingly. Current research on the policy mix has not yet acknowledged the crucial role of procurement personnel competence, as highlighted in the previous section.

7. Assessment of the literature: takeaways and priority research needs

Our survey overall suggests that, if well-designed, PPI can promote innovation. However, more research is needed to draw solid conclusions. In this section we discuss the main takeaways from the literature and outline priority areas for future research. A summary of this assessment is provided in Table 1.

The firm-level evidence gathered so far on the effectiveness of PPI indicates that PPI tends to foster more incremental rather than radical innovation, with young, small, or financially constrained firms benefiting the most, especially when given the flexibility to explore alternative solutions. An emerging literature also highlights the effectiveness of GPP as a catalyst for green innovation. Industry-level evidence suggests that procurement demand shocks in favor of high-tech sectors can have persistent positive effects on their innovative performance. This is for example the case for medical innovation. In addition, PPI appears to have positive spillovers both within and across countries. We believe that further research is needed to validate existing findings and address critical unanswered questions. Specifically, further investigations at the firm level would be valuable for understanding whether the effects of PPI on innovation persist over time. Most of the existing evidence relies on cross-sectional data, while identifying the longer-term impacts, such as the effects on sales, exports, and productivity, would require the availability of long time series. Moreover, additional issues merit further exploration. First, there is a need for additional investigation of spillover effects, that is the impact on firms not directly exposed to PPI, for which micro-level evidence is currently very scarce. Understanding these effects could shed light on broader market dynamics, which is important for assessing whether PPI is pro-competitive. Another area that demands deeper exploration is the role of (innovative) green public procurement as a demand-side environmental innovation policy, which remains under-researched both theoretically and empirically.

Our survey also provides insights into a number of design dimensions relevant for PPI. First, bundling R&D and commercial phases is relatively more advantageous when economies of scope are strong and the innovation is specific to the public sector. Second, granting the buyer enhanced decision-making rights is beneficial when innovation is harder to contract upon, provided the buyer has adequate capabilities. Third, technology-neutral mechanisms can facilitate the exploration of innovative solutions but might come at the cost of excessive rents left to suppliers. Fourth, the effect of increased competition on innovation is ambiguous and depends on the uncertainty in contract specifications and supplier characteristics. Fifth, by boosting demand size, procurement centralization can enhance the impact of PPI as a catalyst for innovation. These insights overall suggest that there is no one-size-fits-all design, but that optimal choices depend on a number of elements including the level of information and abilities of procurers, as well as technology and markets characteristics. While the literature about the relative desirability of bundled versus unbundled approaches is quite developed, knowledge on the other design dimensions is very scarce. This calls for additional research in these areas. In addition, while theoretical insights provide valuable perspectives, in particular to acknowledge the relevant trade-offs underlying different design choices, more empirical and experimental investigation is necessary to assess the applicability and robustness of these findings in real-world scenarios. Moreover, several critical questions remain underexplored in the literature. One particularly critical and policy-relevant question to investigate is how PPI can be designed to encourage radical rather than incremental innovation. This distinction is essential, as current societal challenges, such as climate change, require the development and large-scale adoption of break-through technologies across multiple sectors. Another important and related aspect to consider is the role of risk-benefit-sharing agreements in this context. Understanding how these agreements can be structured to align the interests of public buyers and private firms is essential for mitigating risks associated with innovative projects.

Our survey also indicates that a research agenda is emerging around the influence of buyer capabilities on PPI performance. The empirical evidence gathered so far highlights the importance of procurement personnel and management practices in driving or hin-

Table 1
Assessment of the literature on PPI.

Question	Main findings	Main research needs	Main references
Does PPI spur innovation?	**Firm-level evidence:** PPI can improve the innovative performance of firms, especially small, young and financially constrained ones, if they are given the flexibility to explore solutions. PPI appears to foster more incremental than radical innovation. **Industry-level evidence:** Public demand shocks have a positive and persistent effect on innovation and economic performance. PPI appears to have positive spillovers both within and across countries.	More research is needed to validate existing findings, particularly on long-term effects at the firm level, spillover effects, and (innovative) green public procurement.	Howell (2017), Ghisetti (2017), Czarnitzki et al. (2020), Stojčić et al. (2020), Howell et al. (2021), Krieger and Zipperer (2022), Krieger et al. (2024), Chiappinelli et al. (2025) Finkelstein (2004), Toole (2012), Slavtchev and Wiederhold (2016), Agarwal and Gaule (2022), Clemens and Rogers (2023), Gross and Sampat (2023), Kantor and Whalley (2023), Moretti et al. (2025)
How should PPI be designed to best spur innovation?	Bundling R&D and commercial phases is advantageous when economies of scope are present and the innovation is specific to the public sector. Granting more decision-making latitude to the buyer is beneficial when innovation cannot be contracted upon, provided the buyer has adequate capabilities. Technology-neutral award mechanisms can facilitate the exploration of innovative solutions but at a potential cost in terms of excessive rents left to suppliers. The effect of increased competition on innovation is ambiguous and depends on contract uncertainty and supplier characteristics.	More empirical investigation is necessary to assess the applicability and robustness of theoretical findings in real-world scenarios. More research is needed on design features to encourage radical rather than incremental innovation and risk-benefit sharing agreements.	Rogerson (1989, 1994), Cabral et al. (2006), Iossa et al. (2018), Bruce et al. (2019), Bhattacharya (2021), Che et al. (2021), Ahuja et al. (2021), Fabra and Montero (2022), Kremer et al. (2022)
What barriers hinder the implementation of PPI?	Lack of capabilities of procurement personnel and capacity constraints in procurement offices are important barriers for PPI-induced innovative performance.	More empirical research is needed to validate existing findings, and more theoretical research is needed to further investigate the buyer-innovator relationship.	Bruce et al. (2019), Decarolis et al. (2021), Giuffrida and Raiteri (2021)
What is the role of PPI in the innovation policy mix?	PPI might outperform supply instruments in some circumstances if well designed. Evidence on the combination of PPI with supply-side policies is inconclusive but highlights the risk of crowding out.	More causal evidence is needed on the relative performance of instruments and more theoretical and empirical research is needed on design options to enhance synergies.	Cabral et al. (2006), Aschhoff and Sofka (2009), Guerzoni and Raiteri (2015), De Chiara and Iossa (2019), Stojčić et al. (2020), Czarnitzki and Prüfer (2024)

dering innovation. However, these conclusions stem from a limited number of studies, highlighting the need for more comprehensive investigations into the dynamics between buyers and innovators. Unpacking the black box of the buyer-innovator relationship could enhance the understanding of how bureaucracy can either foster or hinder innovation and inform policies aimed at improving the capacity of public buyers. Additional theoretical work in this area would also be valuable. One relevant question in this context is how to enhance risk management capabilities within the public sector to incentivize radical innovation in the procurement process. This involves accounting for the incentives of the procurement officials, acknowledging that informational asymmetries and preference misalignment relative to regulators or authorities might create room for opportunistic behavior.

Finally, our review of the research assessing the performance of PPI relative to and in combination with other innovation tools provides some insights into the circumstances under which PPI can be superior to supply-side instruments, as well as when integrating PPI into a policy package can yield better outcomes than using instruments in isolation. However, the existing literature on this topic remains limited and inconclusive, especially on whether the combination of PPI with other instruments can generate crowding out effects. Therefore, more causal evidence is needed to identify the specific circumstances in which PPI should be favored over alternative innovation policy measures within the government toolkit, as well as which instruments it should be paired with. This may involve investigating how similar innovative projects perform differently in terms of innovation output when funded and supported by alternative instruments. Additionally, more theoretical and empirical work is needed to explore how different design options for PPI can enhance the synergies between PPI and other instruments.

CRediT authorship contribution statement

Olga Chiappinelli: Writing – original draft, Investigation, Conceptualization. **Leonardo M. Giuffrida:** Writing – original draft, Investigation, Conceptualization. **Giancarlo Spagnolo:** Writing – original draft, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT and Microsoft Copilot in order to improve the use of language and style of the text. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Appendix A

We provide a short characterization of the main PPI instruments currently adopted by classifying them as unbundled or bundled. Iossa et al. (2018) provide this type of categorization for the PPI instruments adopted in the EU. In what follows, we extend this categorization to include PPI instruments from other contexts, particularly from the US, and also incorporate PPI instruments that were recently introduced, such as contracts for difference and advance purchases. Fig. A.1 provides a visual summary of our categorization of PPI instruments.

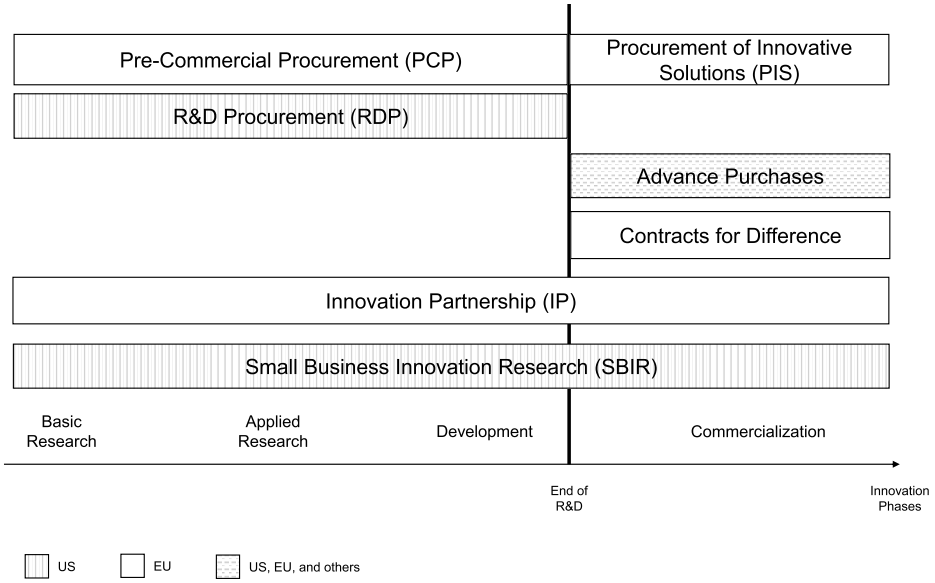
A.1. Instruments with unbundled R&D and commercialization phases

We start with unbundled instruments that only cover the R&D phase.

Pre-commercial procurement (PCP) PCP is an EU instrument for procuring R&D in situations in which an agency's need cannot be readily satisfied by existing market solutions. It is characterized by a competitive step-wise R&D contest, where multiple suppliers develop in parallel alternative solutions, compete, and are shortlisted sequentially on economic and technical grounds along the R&D process stages. In contrast to R&D procurement (see below), where single sourcing is the norm, PCP envisages multiple sourcing, meaning that at least two suppliers should reach the final step and be awarded a PCP contract to maintain competitive pressure until the end of the R&D process and thus avoid *lock-in* (i.e., customer dependence on one vendor) in the subsequent commercialization phase. An additional characteristic of PCP is that risks and benefits are shared between the procurer and contractor(s). See Edquist and Zabala-Iturriagagoitia (2015) and Iossa et al. (2018) for more details.

R&D procurement (R&DP) R&DP is the leading category of unbundled PPI instruments adopted in the US for federal acquisitions. Like other PPI instruments, most R&DP contracts are directed toward objectives when the work or methods cannot be precisely described in advance. Unlike other PPI tools, it envisages a different contest and contract for each R&D stage of a procurement process. In other words, the output of R&DP is a contract between one buyer and one seller to conduct R&D on a specific innovation at a specific stage. Moreover, unlike other PPI instruments but like the other federal procurement contracts, the contract-pricing type is defined ex ante.[29] Similar to a R&DP, a cooperative agreement is a category of grant that involves a higher degree of decision-making authority

[29] Two types of contracts commonly used in the US are fixed-price and cost-plus contracts. In fixed-price contracts, the buyer offers the seller a predetermined price to complete the project. In a cost-plus contract, no price is set, but the contractor is reimbursed for the cost plus a markup. Because of the sizeable ex-ante project uncertainty, the more flexible cost-plus contracts are generally preferred for the procurement of R&D. Approximately 80 percent of R&D contracts over $1 million awarded yearly by federal agencies are cost-plus contracts (source: usaspending.gov). In between are the various incentive contracts, in which the contractor's responsibility for the performance costs and the profit or fee incentives offered are tailored to the uncertainties involved in contract implementation.



Notes: PPI instruments are categorized depending on the bundled or unbundled nature of the innovation phases and the geography of their adoption.

Fig. A.1. PPI Instruments.

on the part of the federal agency (FAR §35.003) relative to standard grants, where typically the agency retains virtually no decision rights. See Bruce et al. (2019), de Rassenfosse et al. (2019), and Decarolis et al. (2021) for more details on R&DP and cooperative agreements.

Moving to the next PPI category, the following unbundled instruments only cover the commercialization phase.

Procurement of innovative solutions (PIS) PIS is an EU procurement process where the contracting authority acts as a lead buyer or early adopter for innovative products that are not yet available on a large-scale commercial basis. As PIS does not include the procurement of R&D services, the latter needs to have been already covered by some other instrument. In this light, PIS and PCP can be seen as complementary. For example, following a successful PCP that has led to the development of a suitable prototype for an innovative solution, the procurer may decide to run a PIS to procure the production of the solution on a large scale. Note that as the R&D and commercial phases are unbundled, the companies awarded with the PCP have no guarantee of also winning a follow-up contract in the PIS. This separation allows companies that have developed innovative solutions outside the PCP framework (e.g., thanks to R&D grants, equity funding, venture capital) to participate in PIS contests on a level playing field with the PCP solution developer. See Iossa et al. (2018) for more details.

Advance purchases This instrument has been used to procure new vaccines. Through advance purchases (such as Advance Market Commitments or Advance Purchase Agreements), governments commit to buying a given volume of doses of effective vaccines at a fixed unit price for doses produced within a specified time frame. By doing so, the buyer finances part of the upfront costs for vaccine R&D and manufacturing—thereby partially de-risking the investments. In exchange, it gets a binding commitment from the companies to build the manufacturing capacity and produce the vaccine before market authorization. This set of instruments aims to ensure that a specific volume of doses can be delivered as soon as the vaccine is authorized. Differently from PIS, where the contract involves the large-scale commercialization of an existing product that has successfully reached the end of R&D, in the case of advance purchases the product has not necessarily been developed yet (see e.g., the case of COVID-19 vaccines). See Snyder et al. (2020) for more details.

Contracts for difference While Contracts for Difference are not necessarily an explicit form of PPI, they can incentivize innovation by hedging investors against risk. These contracts have recently been employed to reduce the regulatory uncertainty that has been a considerable barrier to investment in innovative low-carbon technologies. For example, Carbon Contracts for Difference are being introduced in various EU countries to “buy” non-emitted CO2 emissions in industrial sectors.[30] These contracts, involving a public agency and a company investing in low-carbon industrial technology, are based on an agreed strike price for emission reductions relative to the sector benchmark to guarantee investors a fixed revenue per ton of non-emitted CO2.[31] Carbon Contracts for Difference

[30] These contracts are already in place in the Netherlands and in the process of being introduced in Germany. The introduction of EU-wide Carbon Contracts for Difference is also under discussion.

[31] As long as the CO2 price (e.g., the EU Emission Trading System) is below the strike price, the difference between the strike price and the market price is reimbursed. Investors must return additional earnings if the CO2 price exceeds the strike price to avoid windfall profits.

can therefore limit uncertainty regarding future carbon price levels, thereby facilitating investment in technologies for industrial decarbonization (see, e.g., Richstein and Neuhoff, 2022). Similarly, publicly auctioned Renewable Contracts for Difference or publicly backed Power Purchase Agreements are being used in various countries, including the United Kingdom and Spain, to purchase the production of electricity from renewable sources. They are conceived to reduce regulatory uncertainties in electricity markets with high supply and price volatility. Therefore, they allow project developers to secure low-cost financing, thus reducing power generation costs and accelerating investments in renewables such as wind and solar (Neuhoff et al., 2018; Fabra and Montero, 2022).

A.2. Instruments with bundled R&D and commercialization phases

Other PPI instruments are bundled, as they envisage a single procurement process covering both the R&D and commercialization phases.

Innovation partnership (IP) IP is the main bundled PPI instrument in the EU. The rationale of the follow-on contract that is foreseen under this scheme is to incentivize suppliers to engage in an effort level that is valuable to the buyer throughout the sequential innovation phases. Similar to PCP, it is structured in competitive stages, with the sequential shortlisting of suppliers. The final stage is no longer the development of the solution but the commercialization of the manufactured product or the provided service. The instrument leaves flexibility to the buyer concerning how risks and benefits are shared among parties and whether there should be single or multiple sourcing. See Iossa et al. (2018) for more details.

Small business innovation research (SBIR) One prominent example of bundled PPI instruments in the US context is the SBIR program, a multistage contest designed to support innovative small businesses. It is among the world's largest and most influential government programs to spur innovation among small businesses, amounting to approximately $3 billion across 11 federal agencies in 2018 (Howell et al., 2021). Similar to the IP, the program is structured in a competitive step-wise contest with shortlisting.[32] See Bhattacharya (2021) for more details.[33]

Data availability

No data was used for the research described in the article.

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[32] Another US federal program that aims to provide seed money to move small business scientific innovations from research to practice is the Small Business Technology Transfer (STTR). The main difference between the two programs is mostly whether partnerships with a non-profit research institution are allowed (SBIR) or required (STTR).

[33] Other examples of bundled PPI instruments include the UK's Small Business Research Initiative and the European Commission's EIC Accelerator Pilot. Selviaridis (2020) provides a qualitative study of the former instrument based on interviews with local practitioners. We are not aware of any academic investigation of the latter instrument.

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