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Effects of public procurement of R&D on the innovation process: Evidence from the UK Small Business Research Initiative

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Structured Abstract

Purpose: The study investigates how pre-commercial procurement (PCP) influences the activities, capabilities and behaviours of actors participating in the innovation process. Unlike much of PCP research underpinned by a market failure theoretical framework that evaluates the additionality of innovation inputs and outputs, this paper focuses on the role and capacity of PCP in addressing systemic failures impeding the process of innovation.

Design/methodology/approach: PCP effects on the innovation process were studied through a qualitative study of the UK Small Business Research Initiative (SBRI) programme. Data collection comprised 33 semi-structured interviews with key informants within 30 organisations, and analysis of 80-plus secondary data sources. Interviewees included executives of technology-based small businesses, managers within public buying organisations, and innovation policy makers and experts.

Findings: The UK SBRI improves connectivity and instigates R&D related interactions and cooperation. Through securing government R&D contracts, small firms access relevant innovation ecosystems, build up their knowledge and capabilities, and explore possible routes to market. Public organisations use the SBRI to connect to innovative small firms and access their sets of expertise and novel ideas. They also learn to appreciate the strategic role of procurement. Nonetheless, SBRI-funded small business face commercialisation and innovation adoption challenges due to institutional constraints pertaining to rules, regulations and public-sector norms of conduct.

Research implications: The study contributes to existing PCP research by demonstrating innovation process-related effects of PCP policies. It also complements literature on small business-friendly public procurement measures by highlighting the ways through which PCP, rather than commercial procurement procedures, can support the development of small businesses other than just facilitating their access to government (R&D) contracts.

Policy implications: The study identifies several challenge areas that policy makers should address to improve the implementation of the UK SBRI programme.

Originality/value: The study demonstrates the effects of PCP on the activities, capabilities and behaviours of small businesses and public buying organisations involved in the innovation process.

Keywords: pre-commercial procurement; innovation; small and medium-sized enterprises; public procurement; R&D services; innovation policy

1. Introduction

Public procurement can be used strategically to implement government policy (Harland et al., 2019). Governments, as major customers, have a unique capability to shape and direct supply markets to promote various policy objectives including sustainability, local economic growth, small business development, and innovation (e.g. Kattel and Lember, 2010; Brammer and Walker, 2011; Glass and Essig, 2018). The power of the public purse offers a strong rationale for the strategic role of public procurement: an average of 15% of global annual GDP (over $10 trillion) is spent through government procurement (UNOPS, 2014). In Europe, public procurement expenditure account for around 20% of GDP (European Commission, 2014), with UK expenditure currently forming approximately 14% of GDP (HM Government, 2017).

This paper focuses on the role of public procurement of R&D, widely known as pre-commercial procurement (PCP), in pursuing, in combination, innovation and small business development policy objectives. PCP is defined as the family of approaches entailing government contracting for R&D services that may subsequently contribute to the development of products or services that are currently not available in the market (Rigby, 2016). PCP essentially involves product development and prototyping activities and even the manufacturing of small volumes for field testing, but excludes commercialisation activities. This latter feature makes PCP clearly distinguishable from processes of commercial procurement of innovation (Iossa et al., 2018).

Prominent examples of PCP instruments internationally include the U.S. Small Business Innovation Research (SBIR) programme, the European Union (EU) PCP framework, and the UK Small Business Research Initiative (SBRI). These approaches present some differences in terms of how they are legally defined and implemented in detail. For instance, unlike the U.S. SBIR, the European PCP scheme mandates that public buying organisations must not bear all procurement costs (Rigby, 2016). These approaches, however, also have many characteristics in common. Indeed, the U.S. SBIR inspired the development of PCP schemes in Europe, including the UK SBRI, which follow a competitive process to award R&D contracts in phases. In with the EU PCP instrument, the UK SBRI scheme does not permit

public buying organisations to exclusively own intellectual property resulting from R&D projects (Connell, 2009).

The approaches above that are collectively termed PCP aim to stimulate innovation that contributes to improving the delivery of public services and addressing grand societal challenges (Edquist et al., 2015). In tandem, PCP seeks to support the development of innovative small and medium sized enterprises (SMEs) and the creation of new firms, thereby fostering economic growth (Audretsch, 2003). It is noted that, with the exception of the U.S. SBIR, PCP processes are formally agnostic to firm size and any organisation, including large ones, can compete for advertised R&D contracts. However, in practice PCP policies tend to emphasise public sector engagement with technology-based small businesses and start-ups (Connell, 2017).

Existing research on public procurement policies seeking to promote small business development stresses measures that help remove access barriers and increase SME participation in government contracting (Harland et al., 2019). Such measures largely refer to commercial procurement settings, where SME products are already available in the market. Although SME innovation objectives are noted (Kidalov and Snider, 2011), they do not seem to be the main focus of policy interventions. Discussed measures also underplay settings where the government acts as a 'lead customer' of disruptive technological solutions that are under development by SMEs.

Literature on innovation-oriented public procurement, on the other hand, stresses the functionality of PCP in terms of fostering small business innovation relevant to unmet public sector needs (Connell, 2009). It discusses how small businesses may benefit from PCP and provides evidence of the impacts of PCP policies e.g. in terms of creation of new firms, small firm growth, and employment (Lerner, 1999; Link and Scott, 2018). Such literature is largely underpinned by a market failure theoretical framework and examines how PCP policies address failures related to externalities of knowledge production and to information asymmetries. Existing PCP evaluation studies focus on additionality of innovation inputs (e.g. additional funding small firms attract) and outputs /outcomes

(e.g. number of patents filed; small firm growth and survival rates) that can be attributed to government R&D contracts awarded to small businesses (Link and Scott, 2010; Rigby, 2016).

However, we still know relatively little about the effects that PCP policies have on the *process* of innovation i.e. how they might influence the activities, capabilities and behaviours of small businesses and public buying agencies involved in converting R&D funds and resources to innovation outputs /outcomes (Hughes et al., 2011; Edler et al., 2016). This alternative focus is pertinent since government procurement in general, and PCP in particular, have a role in addressing systemic failures influencing the innovation process (Edquist and Hommen, 1999; Rigby, 2016) such as SME capability shortfalls and limited connectivity and R&D cooperation between small firms and public agencies. Drawing on a systems-of-innovation perspective (Edquist, 1997), this paper seeks to answer the following research question (*RQ): How, and to what extent, does PCP help address systemic failures with a view to facilitating the innovation process?*

This RQ is pursued through an empirical investigation of the UK SBRI scheme based on 33 qualitative interviews and analysis of publicly available secondary data. The UK is a suitable research setting for two reasons. First, the UK Government has placed an emphasis on the SBRI as the country's flagship policy of innovation-oriented procurement (HM Government, 2017). This policy is, in tandem, used as a means to foster public sector engagement with innovative small firms (Innovate UK, 2015). Second, the UK SBRI is a prominent instrument within the wider family of approaches that are collectively labelled PCP. It is the most mature and largest (in terms of number of competitions and total contract value) scheme of its kind in Europe. It is thus more conducive to an analysis of its effects on the innovation process, compared to smaller-scale European PCP schemes.

The study contributes to research on PCP and innovation-oriented public procurement more broadly by shifting attention towards PCP effects on the innovation process, rather than on innovation inputs and outputs /outcomes. Specifically, the study shows how PCP addresses systemic issues related to connectivity, cooperation, learning and capability development, and demand articulation and experimentation. The research also complements the literature on SME-friendly public

procurement policies by identifying multiple ways through which PCP, rather than commercial procurement, supports the development of small firms other than just facilitating their access to government (R&D) contracting. The study also identifies challenges regarding the SBRI implementation that policy makers should attend to improve the effectiveness of the scheme.

The remainder of the paper is organised as follows. The next section reviews the relevant literature, after which the research method is discussed (Section 3). Section 4 presents the analysis and findings. Section 5 discusses the findings and draws out research and policy implications.

2. Literature review

2.1. Public procurement and small business development

Government procurement is used to promote small business development goals (Dennis, 2011; Harland et al., 2019). SMEs face significant challenges regarding their engagement in public sector contracting. These include the inability to bid for large, bundled contracts, stringent pre-qualification requirements in tenders, administrative burden related to bidding, cash flow issues and awareness of tender opportunities (Flynn and Davis, 2015). Accordingly, a wide range of procurement policy measures have been designed to remove access barriers and improve SME participation in government contracting. Harland et al. (2019) studied SME-friendly procurement measures across eleven countries and identified two main categories: financially- and information-oriented measures. The former aim to improve resource availability and capacity of SMEs (e.g. through specialist support, financial assistance, prompt payments, and preferential treatment), while the latter seek to influence SME propensity to engage in government contracting (e.g. through dedicated websites and measuring SME engagement). Factors such as SME tendering capabilities, unbundling of contracts, contract value, and procurement procedure used influence SME success (e.g. Flynn and Davis, 2017), although Glass and Essig's (2018) suggestion that lot-sizing does not contribute to SME success is noted.

The literature is also concerned with the effectiveness of implemented procurement measures. For instance, Loader (2018) suggests that the UK Government's target of 25% SME spending was

ostensibly met and that regulation and enforcement was used to implement SME policies such as the 'contracts finder' tool and the elimination of pre-qualification questionnaires for below-threshold central government purchases. However, there is also evidence of the inability to implement SME-friendly procurement policies in impactful ways (e.g. Kidalov and Snider, 2011; Flynn and Davis, 2015). This is due to tensions between different objectives of public buyers (e.g. sustainability and local growth vs. efficiency and value for money), restrictions placed by EU public procurement regulations and a risk aversion culture (Preuss, 2011; Georghiou et al., 2014).

Overall, the literature on SME-friendly procurement policies refers to commercial procurement settings where SME products and services are market-ready. Although certain studies have noted the relevance of SME innovation outcomes (Aschhoff and Sofka 2009; Uyarra et al., 2014), these do not seem to be in focus. Specifically, this literature stream largely underplays settings of pre-commercial procurement where R&D contracts awarded to small firms are used to stimulate the development of innovative products that do not yet exist (for an exception see Kidalov and Snider, 2011).

2.2. Public procurement and innovation

In the context of innovation policy, public procurement is seen as a distinct demand-side policy instrument aiming to articulate demand for innovative solutions that help improve public services and address grand societal challenges (Hommen and Rolfstam, 2008). Although the deployment of public procurement as a means of instigating innovation is nothing new (e.g. see Rothwell, 1984; Dalpe et al., 1992), its potential has recently re-surfaced as part of an increasing emphasis on demand-side instruments within the innovation policy mix (Edler and Georghiou, 2007).

Evidence of benefits resulting from innovation procurement projects is largely based on case studies of implementation in multiple countries (Edquist et al., 2015; Nijboer et al., 2017). These demonstrate that innovation-oriented government procurement can potentially deliver cost savings, improve public services and generate wider societal benefits (Rolfstam, 2013). Despite positive evidence and a supportive rhetoric internationally (Lember et al., 2014), there is an ongoing debate

regarding the extent to which innovation-oriented procurement processes, as executed by public buyers and in interaction with suppliers, align with relevant policy goals and aspirations (Georghiou et al., 2014). This literature also suggests that the uptake of innovation procurement processes and practices is rather slow (Rolfstam, 2013; European Commission, 2014; OECD, 2014). Implementation challenges range from misaligned incentives, limited use of innovation-friendly tendering practices (e.g. outcome-based specifications), shortfall on innovation procurement capabilities, myopic views of the process of identifying needs, management of uncertainty and risks related to the innovation process, and lack of administrative support systems (e.g. Uyarra et al., 2014; Edquist et al., 2015).

Analysis of effects of innovation-oriented procurement practices on supplier firms does not explicitly distinguish between large and small suppliers. However, the literature draws a distinction between public procurement of innovation (PPI), which concerns large-scale commercial procurement of already tried and tested products (Edler and Yeow, 2016), and PCP. This distinction is relevant to innovative SMEs since PCP entails the unbundling of R&D activity from subsequent commercial procurement, and facilitates awarding smaller R&D contracts to multiple firms (Timmermans and Zabala-Iturriagagoitia, 2013; Iossa et al., 2018). In this sense, PCP is well-placed to contribute towards achieving the twin goals of innovation and small business development.

2.3. Pre-commercial procurement

PCP entails that R&D contract awardees engage in proof-of-concept research and subsequently in product development and prototyping activities (Edquist et al., 2015). With the exception of the U.S. SBIR programme, PCP instruments stop short of commercialisation activities. This has raised doubts of whether PCP is a demand-side policy given a lack of commercial procurement (Edquist and Zabala-Iturriagagoitia, 2015). Nonetheless, there seems to be agreement in the literature that PCP qualifies as a type of procurement since it entails contracts for R&D services (Connell, 2009; Rigby, 2016). PCP tends to be targeted and problem-oriented, rather than general-purpose (Edquist et al., 2015). This means that PCP is often initiated to address a government operational need, although it can also be

used to tackle a generic policy problem facing multiple public and private sector organisations, even cross-nationally (Yeow et al., 2017).

The most widely known PCP initiative is the U.S. SBIR programme, which was established in 1982 to incentivise the engagement of small businesses in US Federal R&D activity and to promote innovative ideas with commercialisation potential. The SBIR programme is mandated meaning that as of 2017 all Federal agencies with an R&D budget in excess of $100 million are obliged to spend 3.2% of that budget for R&D activities performed by small businesses (Small Business Administration, 2014). The SBIR programme resembles a gate-stage model of R&D and operates based on three distinct phases (Small Business Administration, 2017). Phase 1 concerns concept development and focuses on establishing the technical and commercial feasibility of the R&D project. Phase 2 refers to prototyping and seeks to demonstrate the commercialisation potential of the product under development. Phase 3 allows small businesses to pursue commercialisation activities related to earlier R&D work, but involves no further SBIR funding. Federal agencies, as users of R&D results, are responsible for funding additional work during this third phase.

PCP policies in Europe originate in attempts to imitate the U.S. SBIR. First the UK in the early 2000s, and later other European countries developed specific policies for public procurement of R&D (Rigby, 2016). Currently, three PCP schemes operate in Europe: the UK SBRI, the Dutch SBIR and the Flemish Procurement of Innovation scheme designed by the Government of Flanders in Belgium. The European Union has also developed its own PCP framework which is compliant with principles of equal treatment and fair competition, and the avoidance of state aid. This means that compared to the U.S. SBIR, European PCP schemes cannot exclusively target small businesses or directly support their commercialisation activities and growth (Apostol, 2014).

Regarding the impacts of PCP, the literature focuses on the effects of the U.S. SBIR programme because it is the most well-established one. European PCP schemes are relatively recent and as such rigorous evaluations of their effects present challenges (Rigby, 2016). Evidence regarding the U.S. SBIR programme suggests that it provides critical funding that tackles small firms' R&D under-investment

(Link and Scott, 2010), although SBIR funds can also crowd-out company-funded R&D (Wallsten, 2000). SBIR funding enables the creation of new firms and fosters private-sector R&D and subsequent commercialisation activity that would not otherwise had been possible (Audretsch et al., 2002; Link and Scott, 2018). In addition, SBIR contracts lead to spill over effects in the sense that successful project demonstrations motivate more scientists to start new firms. Small firms winning SBIR contracts experience accelerated growth and improve their chances of attracting additional VC funding due to the so-called 'quality certification' effect (Lerner, 1999). Regarding employment growth, evidence suggests that the SBIR's impact is small (Wallsten, 2000; Link and Scott, 2012).

Overall, this literature is informed by a market failure rationale for policy intervention and focuses on the additionality of innovation inputs (funds) and outputs /outcomes of PCP. Innovation policies underpinned by market failure theories stress government intervention to 'fix' failures in finance for innovation caused by positive externalities and lack of incentives of the private sector to invest in early-stage R&D, as well as information asymmetry-related failures (e.g. limited visibility of new firms and their technologies). Accordingly, PCP policies help to address such market failures by funding highly-uncertain R&D at its early stages, incentivising the creation of new firms, promoting small firms with high potential and helping them to attract additional private sector funding, and contributing to small business growth more generally (Connell, 2009; Mazzucato, 2015; Rigby, 2016).

Despite its usefulness, a market failure approach does little to explain how PCP might influence the *process* of innovation in terms of the activities, capabilities and behaviours of participating actors. Examples of process-related issues include the ability of small firms to connect to public sector organisations (as potential customers) and to understand their unmet needs, to engage in cooperative R&D projects with relevant stakeholders, and to develop technical and commercial know-how (Salles-Filho et al., 2011; Iossa et al., 2018). Such issues pertain to system-level deficiencies that potentially inhibit the innovation process, and PCP policies have a role in addressing some of these (Ribgy, 2016). An analysis of systemic failures invites a systems-of-innovation approach to innovation policy design and implementation.

2.4. A systems-of-innovation perspective on innovation policy

The systems-of-innovation approach is one of the dominant theories underpinning innovation policy research and practice (Schot and Steinmueller, 2018). It conceptualises innovation as an iterative process (entailing 'feedback loops') which unfolds between interdependent producers and users of knowledge (Edquist, 1997). The systems-of-innovation perspective goes beyond market incentives as the key driver of innovation activity and emphasises the value of interactive learning and cooperation among economic actors. It also stresses the central role that institutions (e.g. formal rules and regulations, property rights, norms of conduct and culture-driven behaviours) play in the innovation process (Edquist and Hommen, 1999). Institutions, as humanly devised constraints that structure incentives and shape and regulate interactions in economy and society (North, 1990), can either enable or hinder innovation. While some institutions such as a well-developed property rights framework can incentivise R&D activity, others (e.g. dated regulations falling behind technological advancements) can also impede innovation development and adoption (Edquist and Johnson, 1997).

Compared to a market failure theoretical framework emphasising challenges pertaining to externality effects and information asymmetries in innovation markets, the systems-of-innovation approach focusses on systemic failures that impede or slow down innovation (Mazzucato, 2015). These systemic problems refer to a lack of interactions and cooperation among actors, limited access to complementary knowledge and capabilities, weak demand for innovation, technological lock-in and sunk cost effects, limited ability or willingness to adopt innovations, and institutional failures pertaining to formal rules, norms and behaviours (Dodgson et al., 2011; Edler and Fagerberg, 2017).

It follows that innovation policies informed by a systems-of-innovation approach seek to achieve some of the following goals: a) foster connectivity and cooperation among actors, b) promote and incentivise cooperation in R&D and innovation activity, c) support learning and capability development, d) articulate demand for innovative solutions and facilitate experimentation with early-stage concepts or technologies, and e) seek to shape an institutional environment conducive to innovation by mitigating institutional barriers to the innovation process (Dodgson et al., 2011; Edler

et al., 2016). A systems-of-innovation approach is particularly well-suited to conceptualise, analyse and evaluate demand-side innovation policies, and especially innovation-oriented public procurement policy instruments, due to its emphasis on demand-related issues (Edquist and Hommen, 1999).

The existing PCP literature has recognised the relevance of a systems-of-innovation approach e.g. with respect to effects of PCP on SME engagement in government innovation contracting (Rigby, 2016; Iossa et al., 2018). However, we still have a limited understanding of how PCP policies contribute to tackling systemic failures to facilitate collaboration and interactive learning between public organisations and innovative firms, including SMEs, seeking to innovate. The empirical study presented in the following sections seeks to expand our knowledge in this area.

3. Research method

Given the scant empirical research specifically on the role of PCP in addressing systemic failures inhibiting the innovation process, a qualitative research design based on semi-structured interviews (Marshall and Rossman, 1999) was adopted to develop in-depth understanding. The empirical study focused on the UK SBRI, which is the national policy for public procurement of R&D. Similar to the U.S. SBIR programme, the UK SBRI employs a phased approach meaning that participating firms bid for successive R&D contracts. Phase 1 contracts, which are worth £50-100k on average and last up to six months, concern proof-of-concept research for establishing the technical and financial viability of the innovative solution. Companies successfully completing Phase 1 contracts can be invited to tender for Phase 2 contracts for prototype development. Successful bidders are expected to build, test and demonstrate a prototype. This work typically lasts up to two years and is worth up to £1 million.

The role of the SBRI scheme in stimulating innovation in the UK economy has been highlighted in numerous parliamentary reports (e.g. House of Commons Science and Technology Select Committee, 2017). The SBRI is also explicitly referred to in the UK Industrial Strategy as a government procurement tool for instigating innovation and supporting the growth of innovative SMEs (HM Government, 2017). Two recent reviews of the SBRI commissioned by the UK Government (Rigby and

Roper, 2015; Connell, 2017) suggest that although the SBRI has not reached its full potential, it supports technologically-adept small businesses and public sector customers to accelerate their innovation efforts. This study examines these issues systematically and teases out related challenges.

The empirical study comprised 33 semi-structured interviews with key informants within 30 organisations. Appendix 1 provides details of the interviewees, which included policy makers and innovation policy experts affiliated with Innovate UK, the national innovation agency, and the UK Government Department of Business, Energy and Industrial Strategy (BEIS). These individuals were chosen because of their expertise in the SBRI scheme. Three public agencies, operating in the defence, pharmaceutical and healthcare sectors respectively, were also interviewed to understand how and why they use the SBRI scheme. In addition, key informants from 22 SMEs that have participated in SBRI competitions and /or projects were interviewed to elicit data on their views and experiences. These firms were identified through review of publicly available data (e.g. Innovate UK and SBRI Healthcare reports) on SBRI competitions and awarded R&D contracts. The sampling of SMEs intentionally included firms that develop new products and technologies in different public sector application areas. The majority of studied small firms operate within healthcare and defence, but this is not surprising given that the National Health Service (NHS) and the UK Ministry of Defence (MoD) are the two key users of the SBRI. Companies awarded SBRI contracts by the Home Office, the Department for Transport, Department of BEIS and Innovate UK were also interviewed. The sampling mainly focused on small firms that have already been awarded Phase 1 and /or Phase 2 contracts. For comparison purposes, two firms that were unsuccessful in winning SBRI contracts were also interviewed. Table 1 presents the profile of the studied small firms.

[Insert Table 1 about Here]

The interviews were conducted either face-to-face or via telephone with an average duration of approximately an hour. All but five interviews were audio-recorded and fully transcribed resulting

in 478 pages of transcription text. In the instances were audio recording was not possible, detailed written notes were taken and these were revisited and populated immediately after the interviews to maximise data accuracy and validity. An interview guide (Appendix 2) was developed and used in all interviews, although it was applied rather flexibly to consider also the mission and specific context of the buying organisations and small firms studied. The semi-structured interviews covered multiple themes with regard to SBRI policy aims and design, the current uptake of the SBRI by UK government Departments and public sector organisations, implementation approaches and practices, and the perceived effectiveness of the SBRI scheme.

The interviewee accounts were augmented by analysing 80-plus documents and other sources of publicly available data. These sources included UK Government and parliamentary reports, SBRI-related reports and statistics released by Innovate UK, SBRI Healthcare newsletters, MoD press releases and reports, and SBRI evaluation reports. The analysis of these documents helped to complement and triangulate the interview data e.g. with respect to trends in Phase 1 /Phase 2 contract awards by specific public agencies. Such basic quantitative analysis provided further insights regarding the status of SBRI implementation across the UK public sector.

Data analysis proceeded in parallel with data collection, and in an iterative fashion to consider the emerging links between literature and the data (Miles and Huberman, 1994). Data coding was informed by relevant theories, notably the systems-of-innovation and market failure approaches. Data coding and analysis was aided by the ATLAS.ti software. As a first step, all data were stored and organised into an ATLAS.ti software database. Secondly, interview transcripts and documents were read in full to develop some high-level insights regarding the design and implementation of the SBRI. Thirdly, open codes were assigned to interview quotes and document excerpts (e.g. ‘small firm access to market and customers’, ‘networking’, ‘small firm technical knowledge’, ‘small firm learning’). Fourthly, these open codes were refined and grouped into higher-level categories (e.g. ‘small firm connectivity’ and ‘small firm learning and capability development’) using axial coding procedures (Strauss and Corbin, 1990).

4. Findings

This section analyses how, and to what extent, the UK SBRI facilitates the innovation process by addressing relevant systemic failures. In line with a systems-of-innovation approach (Edquist and Hommen, 1999; Edler et al., 2016), five systemic issues that are pertinent to the scope and goals of the SBRI were identified: connectivity and interactions, R&D cooperation, learning and capability development, demand articulation and experimentation with innovative solutions, and small business access to government R&D contracting. The analysis also focuses on whether the SBRI can tackle institutional failures impeding the innovation process, and uncovers associated challenges.

4.1. The role of the UK SBRI in facilitating the innovation process

Table 2 presents evidence regarding the main motivations of small businesses to participate in SBRI competitions and projects, and classifies them according to the four out of the five systemic issues outlined above. Small firms in the sample did not refer to learning and capability development aspects when asked to explain their main motivations for engaging with the SBRI. In addition to the motivations appearing in Table 2, the vast majority of interviewed small firms indicated that another key reason for participating in the SBRI was financial. More specifically, interviewees from small businesses suggested that SBRI contracts provided them with funding to pursue R&D for which the company retains the rights to intellectual property. For many small businesses interviewed this would not had been possible to do without securing a SBRI contract due to lack of funds. Interviewees stressed difficulties to attract venture capital (VC) at early stages of technology development and pointed at the fact that SBRI projects do not require matched funding by the firm i.e. SBRI contracts provide 100% funding e.g. *"SBRI has definitely got a role, it helps you be innovative, it's cheap capital in so far as equity… it's the only scheme that doesn't require equity dilution […] your award is a contract of research and you own the IP in it, there are some caveats to the ownership of that IP, but you own the IP in it, they're paying you to do it, you're going to produce something" (Founder and CEO, S1).*

[Insert Table 2 about Here]

Table 3 summarises the key findings regarding the benefits and challenges of SBRI implementation on the ground, as perceived by the studied small businesses and public buying organisations using the scheme to contract for R&D services. These are, again, presented according to the five systemic issues in focus. Unlike the results of Table 2, multiple small firms highlighted learning and capability development-related benefits arising from their engagement in SBRI projects and tenders. This potentially suggests that small firms become aware of this functionality of the SBRI only after they have engaged in collaborative R&D projects with public buying agencies.

[Insert Table 3 about Here]

In sum, the findings suggest that the SBRI contributes towards addressing systemic problems and appears to have a positive bearing on the activities, capabilities and behaviours of participating small firms and public buying organisations. More specifically, small businesses benefit from expanding their R&D networks and nurturing useful connections, participating in cooperative R&D, acquiring knowledge and developing capabilities, and even generating additional innovation projects. They also become aware of business opportunities in the UK public sector, explore new (or alternative) routes to market, and enter relevant innovation ecosystems.

Public organisations, on the other hand, seem to benefit from connecting with innovative SMEs they had previously been unaware of. They expand their R&D supplier networks beyond existing suppliers and gain access to innovative ideas of small firms. Public organisations that consistently use the SBRI also learn to appreciate the strategic role of procurement in helping them to meet their needs and goals. All these benefits refer mainly to the process of innovation, rather than to innovation funds or outputs /outcomes. They relate to learning, improved capabilities and altered activities and behaviours of small businesses and public agencies. In what follows, the ways in which the SBRI

addresses relevant systemic failures and facilitates the innovation process are elaborated, and associated challenges are highlighted.

4.1.1. Connectivity and R&D related interactions

The evidence presented in Table 2 and Table 3 suggests that the SBRI fosters connectivity and R&D related interactions among small businesses, public sector organisations and other stakeholders e.g. large supplying firms and universities. Multiple interviewees from small firms highlighted the role of the SBRI in providing access to markets and potential customers in the public sector. This finding is also prevalent in Connell's (2017) review of the UK SBRI which was commissioned by the UK Government. This review showed that small firms engaging with the SBRI have been able to identify promising applications of their new technologies and connect to potential customers.

Small firms value opportunities presented during the execution of SBRI projects to engage with relevant innovation ecosystems (e.g. in public healthcare and defence), and to network with relevant actors e.g. public agencies, universities and larger firms. It is noted, however, that a small number of interviewees suggested that such interactions sometimes lack richness in that some government Departments or public agencies have little time to dedicate to small firms and to provide feedback on their product development efforts e.g. *"We expected to engage a reasonable amount with the government and related people in the m-commerce sector and that did not happen" (Technical Director, S21).* All three public buying organisations stressed that setting up SBRI competitions and getting involved in subsequent projects helped them to establish links to innovative small firms and to access their novel ideas and sets of expertise (see Table 3).

4.1.2. *Cooperation in R&D*

The findings suggest that the SBRI incentivises cooperative R&D work intending to address unmet market needs in public and /or private sector application areas. Interviewees both from small firms and public buying organisations confirmed the role of the SBRI in scoping out and funding collaborative

R&D work which can also involve universities and specialist firms (Table 3) e.g. *"we were developing within a consortium a set of technologies around the transfer of heat, summer heat, into winter, seasonal heat transfer so that we could solve the problem of heating from renewable sources […] the fit was good, and SBRI didn't require match funding which is massive and that helps us swarm consortiums much more easily" (Managing Director, S22)*. Through their involvement in SBRI projects, small firms are able to connect to other firms which serve as partners, suppliers or even future competitors. Rigby and Roper's (2015) evaluation of the UK SBRI study, commissioned by Innovate UK, also confirmed this positive role of the SBRI in enabling the creation of cooperative R&D networks.

Many small firm interviewees also noted that they engaged with the SBRI because they had felt that the issued R&D tenders had been a good match to their ongoing product development efforts. A few interviewees also indicated that SBRI competitions fully align with the company's mission e.g. to improve patient outcomes through technology use. A concern raised by two small firms was a lack of coordination among innovation and commissioning units within public buying organisations (Table 3). This fragmented approach can reduce the effectiveness of cooperative R&D and the subsequent exploitation of R&D project outputs.

4.1.3. *Small business learning and capability development*

Several small business interviewees stressed that a key benefit of engaging with the SBRI was building up technical knowledge and capabilities and other types of 'soft' skills (e.g. R&D project management and business plan development) e.g. *"some of the techniques we have developed through both the energy project and the communicability project have been used in other areas […] the techniques or or the things we learned from doing that project we've applied elsewhere" (Technical Director, S20)*. Such learning results from interactions and collaborative work with public agencies, universities and other (larger) firms during the execution of SBRI projects (see Table 3).

Small firms also value the feedback they receive either during the SBRI tendering process or during SBRI contract execution. Such learning can also be useful for adjusting or even radically

changing the direction of their product development efforts e.g. by focusing on specific market applications or exploring new technology areas that hold promise for fulfilling public sector customers' needs (Table 3). SBRI contracts also allowed some of the studied small firms to upgrade their human capital by hiring highly-skilled employees. However, it is not clear whether such investments in human resource upgrading endure after the end of SBRI projects. For example, the firm S13 was able to expand up to 14 highly-skilled employees because of the awarded SBRI contracts, but it subsequently reduced its workforce down to two employees due to the slow process of generating NHS sales. Overall, the findings are in line with Rigby and Roper's (2015) conclusion that small businesses benefit from knowledge transfer, increase their access to specialist skills and even develop additional ideas for innovation projects. The latter was observed, albeit to a limited extent, in the present study too.

A small number of interviewees, nonetheless, stressed the need for closer and more meaningful interactions with potential end users to maximise learning opportunities. Richer interactions with end users help to generate additional feedback regarding potential product use(s) (see Table 3) which, in turn, drives the refinement of product development efforts. Some interviewees also noted that small businesses at early stages of product development may lack knowledge regarding regulatory compliance procedures, which risks delaying or even derailing their R&D projects. This issue was prominent in the healthcare setting. According to an SME interviewee with experience in medical device development projects, for instance: "*the technology which looks promising from a university has been shoe-horned into a project application to fit a user need and the absence of knowledge and skills within any of the parties apart from ourselves about compliance and regulatory affairs has been very, very, very problematic" (Managing Director, S8).*

4.1.4. *Demand articulation and experimentation with innovative solutions*

The SBRI enables UK Government Departments and public agencies to articulate their demand for innovative products and services that potentially solve intractable problems, address policy challenges or improve public services. Analysis of a sample of SBRI tendering documents suggests that a key

feature is the definition of unmet needs or challenge areas often using an outcome- or problem-based approach. An interviewee from P2, one of the public agencies studied, suggested that the SBRI also offers a mechanism to engage with large industry players as the potential end users of R&D results, and to leverage their expertise to co-define unmet market needs (Table 3). This enables designing SBRI competitions that are market-relevant and potentially impactful.

Interviewees from both public organisations and small firms highlighted that the SBRI offers an opportunity to experiment with new ideas and solutions and to 'fail fast' in cases of unsuccessful projects. The Phase 1 /Phase 2 approach to R&D contracting means that public organisations are able to try out radical solutions without assuming excessive financial risks. At the same time, small firms can benefit from early-stage testing of their proposed solutions and use the feedback to make informed decisions regarding the potential of products under development e.g. *"we did the initial SBRI project and came up with a prototype that essentially worked but it was not perfectly fit for purpose […] so we spent almost two years cutting features off the system in order to actually develop something that is more useful. That is a good process [...] the senior management decided to self-fund that part of the project because they wanted to make it as soon as possible" (Project Manager, S14).*

Two interviewees, however, highlighted that the SBRI does not fully realise its role as a catalyst for market change and radical innovation due to implementation fragmentation. Continuity of SBRI tenders, either in terms of frequency of competitions or the lack of consistency in thematic areas addressed, can deter small firms and their investors from planning long-term (Table 3). One interviewee also suggested that the SBRI needs to be better integrated with national or sector-specific innovation strategies and related technology road-mapping exercises: *"It's a problem with the design of the SBRI in [the] context of the big picture […] we need to produce electric vehicles more cost effectively in 20 years' time. The components that we don't understand are batteries, power management cells, computers in cars, whatever. We're going to have an SBRI competition to think about how we could do that in the future […] if the SBRI project is successful you could have then folded*

that into the other programmes you have which take them through development" (Former Director of Innovation Programmes, Innovate UK).

4.1.5. *Small business access to government R&D contracting*

All three interviewees from the studied public organisations noted that the SBRI is a useful mechanism for expanding their network of R&D suppliers. A key SBRI benefit is that it allows them to develop cooperative links with innovative SMEs possessing specialised sets of expertise (Table 3). Multiple interviewees from both small firms and public organisations also stressed that the phased approach to R&D contracting encourages small businesses to participate in SBRI tenders. This is because the small size of contracts (particularly Phase 1 contracts) signals to small firms that they can effectively compete for government R&D business. Unbundling of R&D activity by using Phase 1 and Phase 2 contracts also improves small firms' chances of winning R&D contracts (see Table 3).

The SBRI tends to attract bids mainly from small and micro firms. According to Innovate UK statistics, approximately 75% of all bids come from small businesses. Connell (2017), in his SBRI review, found that more than 60% of SBRI contracts are awarded to SMEs with a large proportion of the rest being awarded to universities, consultancies, or consortia of involving small firms and universities. Larger firms do not seem to seek SBRI funding: *"larger businesses are not so much looking for these sorts of opportunities […] If you've got a great idea you don't need £50,000 from us or anyone else you just get on and do it without the necessity of going through a competitive phase and in the process exposing your idea" (SBRI Account Manager 1, Innovate UK).*

Multiple interviewees also suggested that the SBRI contracting process entails reduced administrative burden as it is easy to participate in tenders, the bidding cycle is relatively short, opportunity costs are low, and R&D contract management and reporting procedures are light-touch (Table 3). Small firms in the sample reported no problems regarding timely payment. These findings are in line with a recent evaluation of the SBRI Healthcare programme by Rand Europe (Lichten et al.,

2017) which concluded that a strength of the SBRI it its low administrative burden for small firm bidders and contract awardees.

Despite all these positive aspects, both small firms and public agencies highlighted SBRI budget limitations and discontinuities (Table 3). This can affect the ability of small firms operating in specific technology areas to sustain and accelerate their product development efforts. Discontinuity of competitions appears to be a challenge particularly in the MoD's SBRI programme. Analysis of secondary data regarding SBRI contracts awarded by the MoD in the period 1 April 2015 to 31 March 2017 suggests that out of 149 awards, only fourteen were Phase 2 contracts. These were awarded to SMEs and universities across four different thematic competitions. The other 135 R&D contracts were of Phase 1-type. This finding suggests that, in the case of the MoD programme, there might be a lack of critical mass of SBRI projects moving from a proof-of-concept stage to prototyping and further development. Connell's (2017) review of the UK SBRI also highlighted this issue.

4.2. Institutional constraints post-SBRI contracting: commercialisation and adoption challenges

Despite the positive influence of the UK SBRI on the innovation process, the research also uncovered challenges facing small firms after successful execution of SBRI contracts. The challenges reported by SMEs relate to their commercialisation activities, the alignment of SBRI contracting with commercial procurement processes, and the ability of public sector customer organisations to adopt innovations at pace and scale. Table 4 provides a summary of the key issues observed. Overall, these findings suggest that the SBRI appears to be less equipped to grapple with broader systemic failures pertaining to institutional barriers, notably regulatory constraints and public sector norms of conduct and behaviours that are not conducive to innovation.

[Insert Table 4 about Here]

Many of small firm interviewees expressed concerns regarding their ability to commercialise SBRI-funded technologies, and noted that it is not clear to them what additional support is available after the completion of Phase 2 contracts. Unlike the U.S. SBIR programme which includes a formal Phase 3 for commercialisation activities and actively promotes the small businesses and technologies it funds, the UK SBRI stops short of commercialisation support due to the need to comply with the EU PCP legal framework. This can be problematic for small businesses that are less able to secure follow-up finance, or have limited resources to invest in commercialisation and sales development activities (Table 4). Interviewees from public organisations and Innovate UK admitted that this regulatory requirement creates a gap between the successful completion of Phase 2 contracts and full commercialisation.

In accordance with the EU PCP framework, the SBRI process is distinct from commercial procurement procedures. This means that a separate and independent tendering process is required for the large-scale commercial procurement of the SBRI-funded products to ensure that principles of competition and equal treatment are adhered to. There is essentially no guarantee to SBRI-funded firms that their innovations will be procured and adopted at scale. Many of the studied small businesses recognised such regulatory restrictions, but they also pointed at misaligned incentives and limited budgets as additional challenges with respect to commercial procurement (see Table 4).

Several interviewees also highlighted the significant difficulties that small firms encounter when trying to sell their innovations to large public buying organisations, such as the NHS and the MoD. Innovation adoption challenges seem to result from rigid professional norms of conduct, risk-aversion behaviours, and bureaucratic procedures within public organisations that discourage innovation (see Table 4) e.g. *"It almost makes no sense to fund the early part of the development; you get all these fantastic innovations coming through when the only possible customer that we have in the UK – and there really is only one customer, that's the NHS – is institutionally incapable of adopting or using them" (CEO, S5).*

These findings are corroborated by three prominent SBRI policy evaluations (Rigby and Roper, 2015; Connell, 2017, Rand Europe, 2017) that highlight very similar challenges facing small businesses regarding commercialisation and adoption of their innovative products by public sector customer organisations. Connell (2017), for example, noted the weak pull-through of SBRI-funded technologies in the UK public sector.

It should be emphasised that addressing such wider institutional failures is beyond the remit of the SBRI scheme *per se*, and it would thus be inappropriate to assess the effectiveness of this policy instrument using this criterion. These issues, nonetheless, clearly hinder the ability of small businesses and public buying organisations to maximise the value they gain from government R&D contracting. It is also noteworthy that some of the small firms in the sample that have yet to commercialise their SBRI-funded products referred to process-related benefits (e.g. networking, capability development and R&D process acceleration) as 'intermediate' or 'latent' ones e.g. *"I think definitely most of the stuff that we've done through CDE, you might call it potential long-term benefit because it's too early to say and it requires a lot of work to exploit it further. But I'm not going to say it's a derived benefit, it's not being realised" (CEO, S19).*

5. Discussion and conclusions

The RQ posed in the introduction asked how, and to what extent, PCP helps in addressing systemic failures in order to facilitate the innovation process. The empirical findings highlight five main ways through which the UK SBRI, as one of the prominent PCP instruments internationally, can positively influence the activities, capabilities or behaviours (Hughes et al., 2011; Edler et al., 2016) of small firms and public buying organisations seeking to innovate. More specifically, the empirical study highlights how the SBRI contributes to addressing systemic failures (Dodgson et al., 2011; Rigby, 2016) by improving connectivity, R&D related interactions and cooperation of small firms and public buying organisations. Despite the fact that the UK SBRI is accessible also to large firms, the available evidence suggests that it tends to stimulate engagement mainly with technology-based small businesses.

Through securing government R&D contracts and carrying out SBRI-funded R&D projects, small firms get access to relevant innovation ecosystems, build up their knowledge and capabilities, and explore possible routes to market for their products under development. Public organisations, on the other hand, use the SBRI scheme to connect to innovative small businesses and to access their sets of expertise and novel ideas. They also appear to alter their attitudes regarding the role of public procurement in meeting their operational needs or policy goals.

However, the UK SBRI clearly faces limitations in terms of its scope and ability to grapple with wider systemic failures relating to the institutional environment within which innovation development and adoption processes unfold (Edquist and Johnson, 1997). Specifically, the research uncovered commercialisation and innovation adoption challenges facing small firms after the completion of their SBRI contracts. These challenges result from regulatory constraints, rigid norms of conduct, bureaucratic rules and risk aversion behaviours within the UK public sector that collectively slow down or even impede small business-driven innovation.

Regarding regulatory constraints pertaining to the legal framework underpinning the implementation of the SBRI (i.e. lack of commercialisation support and lack of commitment to procure the developed solutions), it is feasible that public buying bodies could lift some of these constraints by using the EU Innovation Partnership procedure (Iossa et al., 2018). More broadly, in European policy making and public procurement practitioner circles alike there have been debates as to whether PCP and the Innovation Partnership procedure overlap significantly. The author's current research in the UK and the Netherlands suggests that there is convergence towards the view that both approaches add value, and that each may be favourable under certain conditions. In practice, some key factors driving the choice between PCP and the Innovation Partnership procedure include technology and market maturity, the level of the public agency's commitment to procure the innovation under development, and the preferred allocation of intellectual property (see also PIANOo, 2020). In addition, the Innovation Partnership approach is often less suitable for engaging with SMEs due to the bundling of the R&D and large-scale production phases under the same contract (Iossa et al., 2018).

Nevertheless, it is possible to use both approaches in a synergistic way, especially when PCP projects can help the public buying body to gain knowledge and understanding of technical possibilities, which can subsequently feed into the development of specifications for an Innovation Partnership project.

A comparison between the empirical findings and the systems-of-innovation literature reveals three main differences with respect to the proliferation of systemic failures, and how these are addressed. First, the findings suggest that the UK SBRI does not fully tackle systemic failures related to the supply of finance (Edler and Fagerberg, 2017) as a way to incentivise cooperative R&D activity. Although the SBRI provides 100% funding for R&D to participating firms, both the SMEs and the public agencies interviewed suggested that budgets for SBRI competitions and projects tend to be limited and /or discontinuous. Second, the empirical findings did not cover possible systemic failures pertaining to technological lock-in or sunk cost effects (Dodgson et al., 2011), although some interviewees hinted at such issues by suggesting that SBRI competitions need to be embedded in wider technology road-mapping strategies. Third, some types of institutional failures affecting the ability of small firms to engage effectively with large public organisations (e.g. such as the NHS) were not addressed by the empirical study. Such institutional failures relate to structural and governance aspects of public service delivery systems. For example, rules for activity-based hospital re-imbursement methods in the NHS often impede the adoption of innovative technologies that would entail transfer of healthcare activities out of hospitals and into primary care.

Overall, the findings regarding the effects of the UK SBRI on the innovation process are potentially transferable to other countries that use similar PCP instruments to stimulate technological innovation and to support small businesses. Recent research on the U.S. SBIR programme (Link and Scott, 2018; Audretsch and Link, 2018), for instance, emphasises three relevant process issues: small firm behaviour regarding R&D project selection, knowledge development patterns, and the relevance of small firms' human, social and reputational capital. Specifically, SBIR contracts enable American small businesses to shift their R&D activity towards riskier innovation projects (i.e. projects with lower chances of commercialisation) with potentially higher returns. Choosing to pursue more ambitious

R&D projects also means that such firms develop critical technical knowledge and build up capabilities that might eventually contribute to future commercialisation outcomes (Link and Scott, 2018; Audretsch and Link, 2019). The human, social and reputational capital of small firms funded by the U.S. SBIR is also found to contribute to their success (Audretsch and Link, 2018). This implies that developing dense connections and R&D interactions and being able to attract highly skilled employees are intermediate benefits for SBIR-funded firms. The upshot here is that the U.S. SBIR programme is also concerned with process-related issues, which is perhaps best captured, albeit only implicitly, in the first legislated purpose of the programme referring to 'stimulation of technological innovation' (see Link and Scott, 2018).

The findings are also potentially transferable to settings of PCP implementation in countries such as the Netherlands. A recent evaluation of the Dutch SBIR programme (Dialogic, 2017) stressed process-related benefits for R&D contracts awardees. These include forming a customer relationship with Dutch government departments, collaborating with other small firms, exploring potential solutions and related risks, thinking about market opportunities, and getting valuable feedback regarding the proposed solution and learning from such feedback e.g. developing capability in writing a business plan for commercialisation. Despite such benefits, the evaluation also suggested that commercialisation of SBIR-funded innovations is challenging given the limited role and support of public agencies during the commercialisation phase, and their loose commitment in terms of commercial procurement (Dialogic, 2017).

In conclusion, the findings regarding SBRI effects on the innovation process are potentially transferable to other countries implementing PCP approaches. PCP can positively influence the activities, capabilities and behaviours of economic actors. However, after the completion of the PCP process commercialisation and innovation adoption outcomes appear to be impeded by regulatory and other types of institutional constraints.

5.1. Research implications and contributions

The findings extend the existing literature in two main ways. First, the study contributes to PCP research by shifting attention towards the effects that the UK SBRI has on the process of innovation, rather than on inputs and outputs /outcomes and their additionality (e.g. Learner, 1999; Wallsten, 2000; Audretsch, 2003; Link and Scott, 2010). More specifically, the study demonstrates how the SBRI can address systemic issues facing economic actors regarding connectivity and interactions, R&D cooperation, capability development, and demand articulation and experimentation with innovative ideas. Given that the UK SBRI shares common characteristics with other key PCP instruments, the findings suggest that PCP has a positive influence on the activities, behaviours and capabilities of small firms and public organisations and facilitates the innovation process (see also Link and Scott, 2018).

The research also uncovered commercialisation and innovation adoption challenges facing technology-based small businesses. These originate in the limited ability of the UK SBRI to tackle broader institutional failures pertaining to regulatory, procedural and behavioural constraints. It is likely that such findings are less relevant for the U.S. SBIR programme, in that the latter does more to support commercialisation activities of small firms it funds (Audretsch and Link, 2018). These insights suggest that research on the evaluation of PCP instruments in European countries (e.g. Rigby, 2016) should pay more attention to the moderating effects of some of these institutional failures on PCP outcomes and impacts.

Second, the study complements the literature on small business-friendly public procurement measures (e.g. Kidalov and Snider, 2011; Loader, 2018; Harland et al., 2019) by highlighting the multiple ways through which PCP (rather than commercial procurement) can support the development of innovative small firms, other than just facilitating their access to government (R&D) contracts. In particular, the research shows that small businesses that win government R&D contracts enter relevant innovation ecosystems and engage in R&D projects whose execution is beneficial in terms of developing connections, establishing contractual (customer) relationships with public

organisations, developing technical know-how and capabilities, and exploring potential technology applications and routes to market.

As compared to commercial procurement-related policy measures designed to enable participation of small firms in government contracts (e.g. Flynn and Davis, 2015; Glass and Essig, 2018), the UK SBRI and other similar PCP approaches are likely to target a narrower pool of small businesses that are nascent or very young, technologically adept, creative, and highly specialised (Audretsch and Link, 2019). This might explain why PCP policies are well placed to foster the specific set of process-related benefits outlined above e.g. emphasis on capability development of small firms and their formation of cooperative R&D relationships with relevant stakeholders.

5.2. Policy implications

The research presents implications for the implementation of the UK SBRI. The research identified certain challenge areas (Table 3) that need addressing. In particular, policy makers should better integrate the UK SBRI into national or sector-specific technology and innovation strategies in order to increase its use across UK Government departments and public agencies. In tandem, additional budgets should become available for SBRI competitions and contracts, especially of Phase 2-type. These measures would enable a more structured approach and improve continuity of SBRI contracting. In addition, there is a need to stimulate even richer interactions between SBRI-funded firms and public organisations, and especially end user communities. Coordination between different functional areas (e.g. R&D and procurement) within large public organisations such as the NHS and the MoD also needs improving.

Policy makers should also tackle the observed gap between the successful completion of Phase 2 contracts and full commercialisation of SBRI-funded technologies. Given the lack of a clear route to commercial procurement of SBRI-funded products due to regulatory constraints, two courses of action would be possible: a) clarify to small firms and signpost what form of support for commercialisation activities is available, and b) do more to increase awareness of promising firms amongst investors and

potential customers. The post-Brexit policy landscape potentially offers additional opportunities for active support of SBRI-funded firms (in line with the U.S. SBIR programme), if the UK was to deviate from EU public procurement laws and regulations.

Additional effort is also required to accelerate the adoption of SBRI-funded innovations by fostering an innovation culture with large public sector organisations, and by shaping positive incentive structures (e.g. recognition of successful projects or performance-related bonus payments) to mitigate conservative attitudes of some civil servants and procurement professionals towards innovative technologies. Certain initiatives already in place (e.g. Academic Health Science Networks and the Accelerated Access Collaborative within the NHS) should be further supported and amplified to help increase the rate and scale by which technology-based SMEs and their new products /services penetrate public sector supply chains.

5.3. Limitations and future research

The study presents limitations that warrant further research. First, the empirical study focused on the UK SBRI scheme as the setting for studying the effects of PCP on the innovation process. Albeit the findings are potentially transferable to other countries implementing PCP policy (see relevant discussion above), future research should explicitly aim at conducting a comparative analysis of PCP effects across countries. Such an endeavour might be useful, for instance, in terms of identifying country-specific institutional factors (North, 1990) hindering or enabling the innovation process.

Second, the research focused on innovation process effects and studied those using an inductive, qualitative research design. Further research, of quantitative nature, is needed to establish links between these process effects (and related benefits) and the final outcomes and impacts of PCP e.g. in terms of commercialisation of technologies and long-term survival of small firms. This line of research should identify suitable (proxy) measures for studying process-related effects and their links to key outcomes, and make use of any existing data sets for econometric analyses (Onken et al., 2019).

Notwithstanding these limitations, the study provided in-depth insights regarding the role of PCP in addressing systemic failures and its positive influence on the activities, capabilities and behaviours of innovative small firms and the public organisations they engage with. More broadly, and in keeping with the focus of this Special Issue, the research opens up a fruitful avenue for further research on the strategic role of public procurement in pursuing, in tandem, innovation and small business development policy goals.

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Appendix 1. List of interviewees

Organisation	Interviewee Role
Policy makers and innovation policy experts	
Department of BEIS	Assistant Director: Innovation Procurement Policy
Innovate UK	SBRI Account Manager 1 [interviewed twice]
Innovate UK	SBRI Account Manager 2
Innovate UK	Regional Innovation Manager, NW England
Warwick University	Former Director of Innovation Programmes at Innovate UK
Cambridge University	Expert and co-designer of the UK SBRI scheme
The RSA	Research Associate with expertise in the UK SBRI
Public buying organisations	
P1	Head of Operations
P2	Head of Innovation (SBRI Programme Manager)
P3	Chief Operating Officer; Assistant Commercial Director
Small businesses	
S1	Founder and CEO
S2	Co-founder and CEO
S3	CEO
S4	CEO
S5	Founder and CEO
S6	CEO
S7	Senior Innovation Manager
S8	Managing Director
S9	CEO
S10	CEO
S11	Co-founder
S12	CEO
S13	CEO
S14	Project Manager
S15	Chief Executive
S16	Co-founder and Managing Director
S17	CEO
S18	CEO
S19	CEO
S20	Technical Director
S21	Co-founder and Technical Director
S22	Co-founder and Managing Director

Appendix 2. The interview guide

Generic questions

- Interviewee and organisation background information
- Public procurement of R&D: UK policy design and aims
- Overview of the SBRI process (implementation aspects)

Small business-focused interview themes

- Motivations to bid for SBRI contracts
- Objectives regarding participation in SBRI projects
- Description of the product /technology under development
- Information re: number of tenders, contracts and funding amount
- SBRI tendering process: views and experiences
- Perceived benefits of the SBRI
- Perceived challenges of the SBRI
- Perceived quality and value of the SBRI programme
- Commercialisation and adoption issues and effects
- Current status and next steps

Public organisation-focused interview themes

- Motivations to adopt and use the SBRI
- Main goals regarding use of the SBRI
- Description of how the SBRI is implemented
- Information about tendering process and contract awards
- Capabilities required
- Engagement with small firms
- Perceived benefits of using the SBRI
- Perceived challenges regarding the SBRI process
- Perceived value of the SBRI
- Links to commercialisation and commercial procurement processes
- Innovation adoption issues and effects

Table 1: Profile of the technology-based small businesses included in the study

Firm	SBRI Phase(s)	# R&D contracts	Public sector area	Description of innovative solution(s)
S1	Up to Phase 2	2	Healthcare	Screening solution (ECG device) for cardiac arrhythmias
S2	Up to Phase 2	2	Healthcare	E-platform connecting pharmacies with patients and clinicians
S3	Up to Phase 1	1	Healthcare	Transdermal Fluid Removal (TFR) technology
S4	Unsuccessful bids	0	Healthcare	E-medical records and data sharing solution
S5	Up to Phase 3	2	Healthcare	Sleep mask for treating diabetic retinopathy
S6	Up to Phase 2	2	Healthcare	Enuresis solution based on radio-frequency technology
S7	Unsuccessful bids	0	Healthcare	Bed capacity management solution for hospitals
S8	Up to Phase 2	2	Healthcare	Technology to diagnose faecal incontinence in patients
S9	Up to Phase 2	7	Healthcare	Application for self-management of persistent pain (chronic pain)
S10	Up to Phase 1	1	Healthcare	Accurate respiratory monitoring technology
S11	Up to Phase 1	1	Healthcare	Technology to assist communication of disabled children
S12	Up to Phase 2	4	Healthcare; Transport; Innovate UK	Multiple technologies e.g. assisting patients with brain injury in cooking
S13	Up to Phase 3	3	Healthcare	Hand-hygiene solution to combat hospital infections
S14	Up to Phase 1	1	Healthcare	Device to prevent bed falls for elderly people
S15	Up to Phase 2	2	Healthcare	Digital application to support patients with dementia to manage their hospital appointments
S16	Up to Phase 1	3	Defence	Military radio communications technologies
S17	Up to Phase 1	1	Defence	Virtual training technology applications to defence
S18	Up to Phase 2	3	Defence; Security	Infrared imaging and detection technologies
S19	Up to Phase 2	30+	Defence; Security; Healthcare; Innovate UK	Multiple technology areas e.g. antenna and communication for security
S20	Up to Phase 2	5	Defence; Security; Energy	Translational data analytics technologies
S21	Up to Phase 2	2	Security	Anti-counterfeiting technology for product and internet security
S22	Up to Phase 3	2	Energy	Renewables / solar PV metering and monitoring technology

Table 2: Reported motivations of small businesses for participating in SBRI competitions and projects

Small business motivations	Systemic issues	Indicative interview quotes
Access to market and potential customers Engagement with public sector innovation ecosystems Networking with relevant stakeholders	Connectivity and interactions	*"We saw this opportunity as more than the funding, a lot more than the funding. This was our first easy gateway into interaction with the NHS, getting to understand more about the ecosystem and the funding that comes with it, but mostly about getting into that ecosystem because, eventually, what we are building is a product that is designed for the entire healthcare system" (Co-founder and CEO, S2)* *"One of the other contracts was looking at a device which was supposed to be trialled in Alder Hey Hospital and through that contract we've been able to make contacts there which, again, have been incredibly useful to us. So, we are pretty well connected and we've had an awful lot of mission input and potentially user input" (Managing Director, S8)*
Engage in cooperative R&D to address unmet needs Accessing other firms' expertise through cooperation Aligned goals: SBRI tenders fit for purpose	Cooperation in R&D	*"We led the project and it allowed us to subcontract to partners such as the University of Liverpool, Digital Catapult and regular retail specialists […] the SBRI definitely was the catalyst to bring us together" (CEO, S12)* *"It [the SBRI] allows you to work with companies which you wouldn't work with otherwise. That's a big positive […] it allows us to work with the cutting edge companies in our sector some really smart Cambridge based companies, the work we did was down there so it opened a new ecosystem for us so that was really good" (CEO, S12)* *"It was a good… in terms of the call focus, it was a good match, because the objective of the call was to identify solutions that could help to reduce hospital admissions and emergency care, so this is exactly the value proposition of the technology we are developing" (CEO, S3)*
Experimenting with technology and its application in public sector uses	Experimentation with innovative solutions	*"In our business, we need to stay at the forefront of the technology and we have to get through some technical risks so the SBRI funding allows us to have a non-dilutive source of funding to demonstrate the technology to hopefully get it to a point where there would be either demonstrations to customers, so there is a customer pool or demonstration to investors where there is an investment to refine the product further" (CEO, S18)*
Light-touch administration of SBRI tenders and contracts	Small firm access to government R&D contracting	*"SBRI is much more focused so it reduces opportunity costs, it reduces the entire cycle and probably the most important thing is that it brings you in direct contact with your end customer, which is the NHS" (Senior Innovation Manager, S7)* *"We are a big supporter of the SBRI model. We think that it has been carefully designed to be SME friendly. So, the focus on deliverables and outcomes of the project as opposed to activity and monitoring activity and monitoring how moneys are defrayed is, we think, a much more intelligent way of governing this kind of project" (CEO, S9)*

Table 3: Perceived benefits (+) and challenges (-) of SBRI implementation for participating small businesses and public buying organisations

Small businesses	Public organisations	Systemic issues	Indicative interview quotes
(+) Accessing and engaging with potential customers (+) Connecting and engaging with multiple stakeholders e.g. universities, other small firms, large suppliers and investors	(+) Establishing links and actively engaging with innovators, SMEs and research institutions	Connectivity and interactions	*"One of the challenges facing medical device companies is getting access to the most stakeholders on the value-based healthcare system, patients, doctors, nurses, procurement people. That can be quite challenging. The SBRI offers a mechanism for [S10] to approach all stakeholders to really road test the proposition within a new market, the UK market. What that helps us to do is accelerate time to market because we get ample access to the right people to figure out what their needs and wants are" (CEO, S10)* *"[…] they [P1] were trying to get a small business to collaborate together, that was good. They had an event where all the winners got together and the idea was can you collaborate with some of the others. It worked very well actually because some of the others had a similar idea but on a different area so maybe some of them were looking at more user interface or visualisation of your results as we were the ones producing the results so that was a really good idea" (Technical Director, S20)* *"Croydon Hospital […] was going to be our pilot site; so they had to be on board. Kingston University was with all our experts in requirement solicitation, we collaborated with the Department of Pharmacy in particular and they are very good at interfacing with the clinical side and extracting requirements and in general formulating the business solutions" (Senior Innovation Manager, S7)* *"The main idea is to engage with established defence suppliers, SMEs and academia and invite them to come up with solutions for us" (Head of Operations, P1).*
(+) Collaborative R&D with other public organisations, large and small firms and universities (-) Fragmentation and lack of coordination among units within government department	(+) R&D collaboration with small firms, large firms and universities	Cooperation in R&D	*"So, to all intents and purposes we're working together to see if we can make a meaningful improvement in the efficiency of the NHS and in this particular instance to improve patient flow as partners or collaborators" (CEO, S10)* *"We use it [the SBRI] as a mechanism to be able to work under the pre-commercial procurement framework. It allows us to work with academics, businesses, in the UK and EU because there are various schemes, as I say, to get these new technologies developed where there is a gap between the academic capability and the fit for purpose spaces for technologies for use in large industries" (Head of Innovation, P2).* *"DSTL has to plan many, many years ahead, sometimes 20 years ahead […] but they can't make the procurement managers in the Ministry of Defence adopt that technology. There's a big gap and there's a big gap also in mentality, because DSTL tend to be scientists pushing technology whereas Ministry of Defence tends to be operational pull" (Co-founder and Managing Director, S16).*
(+) Building technical knowledge and capabilities (+) Adjusting direction of technology development efforts	No evidence	Learning and capability development	*"So, what [the SBRI] has really done for us is that because we've been so exposed through the project to…it's been real knowledge gathering exercise for us in that the interactions we've had with people within the NHS and specific regulatory and compliance organisations related to our work has really beefed up our knowledge. So, as a business, now, we have got a lot more to sell. We've gained a huge amount of knowhow, experience through the process" (Managing Director, S8).*

(+) Developing additional innovation ideas /projects (-) Lack of rich interactions with end users and limited feedback in some cases			*"So, off the back of that project we got to further develop some applications that we had been working on ourselves, doing our own R&D and it allowed us to get some of our ideas closer to market" (CEO, S12)* *"When we won that first CDE contract, that was really... opened many doors for us, because that got us in touch with a technical partner within DSTL what are called technical partner […] he comes and the first thing he does is tell you what's wrong with your bid, because you may not be bidding for quite the right technology area that DSTL has in mind. So he has a lot of influence on the direction of the business […] the technology areas that he brought us into was military radio communications" (Co-founder & Managing Director, S16)* *"I would say that one of the improvements could be better access to people like that; serving officers or trainers […] and we were already told in the brief that it's going to be next to impossible to get these people to help you out so don't … it actually said don't start your project with requirements capture because they won't… And I was like "oh, that is where I would normally start." (CEO, S17).*
(+) Early-stage testing and feedback regarding potential of innovative product /idea (-) SBRI does not allow long-term planning due to fragmented approach	(+) Phased SBRI approach enables experimenting with new technologies at low risk (+) Collaboration with large suppliers to define unmet market needs (+) Appreciating the strategic role of procurement and its contribution to meeting organisational goals	Demand articulation and experimentation with innovative solutions	*"It [the SBRI] gives us a mechanism to succeed and fail quickly and relatively cheaply. So if this is going to fail, let's have it fail in three months at a cost of £30,000 rather than two years at a cost of £0.5 million" (SBRI Account Manager 1, Innovate UK).* *"Our challenges are all run in collaboration with large industry sponsors, in the main […] what we want to do is develop a product at the end of it that can then be accessed by the scientists in these large industries, whether it be for service, they buy a product and what it allows us to deliver our impact on the animal use while supporting businesses developing these new scientific technologies that, actually, are of benefit" (Head of Innovation, P2).* *"The model of SBRIs in general is too random. In other words, go quiet for six months and then a new call comes out […] So rather than being a sustained prize that you can say, 'Well, this funding is available and we know it's going for the next five years, so let's, based on that, make an investment so that sometime during the next five years we can have a chance at some of those calls.' That's not the case […] Instead, you just have to make your product and if you're lucky that your product can qualify for their funding, then great" (CEO, S4)*
(+) Phase 1-2 approach facilitates access to government R&D contracts (-) Limited and /or discontinuous budgets for SBRI projects	(+) Expanding R&D supplier network to include small firms and start-ups (-) Limited budgets for SBRI competitions	Small firm access to government R&D contracting	*"[…] We really want to engage with populations we haven't engaged before in order to build up a much wider network of research and development suppliers. So we are looking for stuff with relatively low level of maturity that we can get value out of" (Head of Operations, P1).* *"We definitely favour applying for a phase1/phase2 approach […] so that's about letting the SMEs have a chance because the problem is that if you go straight into a half million to two-million-pound project why would we even apply for that if we know we're going to be up against companies that are going to put a couple of dedicated people on it for three months to write out the bids" (Co-founder & Managing Director, S22).* *"We try as much as we can, yes, we'd like to do more but, as I say, it's a resource and budget issue" (Head of Innovation, P2)*

Table 4: Institutional constraints influencing commercialisation and adoption of SBRI-funded technologies and products

Key challenges	**Systemic issues**	**Indicative interview quotes**
Limited support for commercialisation activities coupled with lack of small firm resources for commercialisation work	Institutional constraints: PCP regulations	*"I think whatever support SBRI can do to bridge across commercial sources of finance would be good. I think it is still quite difficult for companies, particularly companies whose business model is selling into the NHS to raise finance because the NHS sales cycle is seen as being very long, it's quite political, it's quite brittle" (CEO, S9).* *"We can go so far but we either run out of cash because the revenue never happens; engagement with the NHs is massively costly […] most private equity funds have a 3- to 5-year cycle. That does not match engagement with the NHS or the innovation cycle […] And, if you're trying to get private equity funding in the UK based around engagement and, ultimately, commercialisation, then you are going to crash and burn, you are going to run out of cash" (CEO, S5).* *"Now I've developed something from SBRI, they've given us 100 grand to develop some wonderful piece of software, an app, smartphone app. How do I now get this smartphone app adopted by the NHS? Well NHS England want me as a small business to try and go out and sell with my one sales director and my two technical support guys to 221 Clinical Commissioning Groups. Now for me to get in to see those Clinical Commissioning Groups is a big marketing effort and a lot of manpower" (CEO, S1).*
Lack of commitment regarding commercial procurement of innovative products /technologies	Institutional constraints: PCP regulations	*"I mean SBRI, because it is pre-commercial procurement, has to stop short of procurement […] So what does particularly a small business do in those circumstances and we've been working hard to try to bridge that gap but we're not allowed to just issue them with a procurement contract" (SBRI Account Manager 1, Innovate UK).* *"[…] internally within the NHS, the side that we're dealing with, with regards to sourcing the product, it's still separate and not exactly integrated with the side that actually brings the product to practice, that commissions the product and gives the product a recurring payment structure" (Co-founder and CEO, S2).*
Commercial procurement goals incentives not conducive to small business innovation	Institutional constraints: public procurement rules and procedures	*"[…] the principal benefit of the device is probably in social care budgets. The people who might buy it are in community healthcare and because it's new, they don't have the budget for it. This is the problem that loads of SBRI projects face […]. If it were not innovative, it wouldn't get the SBRI funding. Yet, the fact that it's innovative means there's no budget for it" (Managing Director, S8)* *"What that procurement department will do is buy the injection and then sell it up and mark it up to the CCG at a profit. And then they tell us they're making a profit as a department. And they say well, if we use your mask, we're going to lose all this revenue. We point out the revenue is fiction, it's a book-keeping exercise and what we're trying to do is look for savings. They say no, if we don't spend the money […] we lose the budget" (CEO, S5).*
Barriers to innovation adoption at pace and scale	Institutional constraints: norms of conduct and behaviours within the public sector	*"One of the barriers to adoption is exactly that [culture and behaviour]. So something that I refer to is if you're a doctor the first thing you get taught in med school is do no harm. You tend to then stick to what you know […] and you're risk averse therefore because you want to do the right thing for the patient. Actually that's slightly at odds with innovation because it makes you more traditional, makes you stick to what you know rather than actually look at what the art of the possible might be" (Assistant Commercial Director, P3)* *"A key reason [why it is difficult to see into the NHS] is institutional capture. There are so many committees, you go to a meeting and there need to be multiple people attending. These people are risk averse and they prefer not making decisions so as not to be held accountable, take risk and get fired. Nobody is held responsible for not making the right decisions" (CEO, S13).*