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THE IMPACT OF SPACE PROCUREMENT ON SUPPLIERS: EVIDENCE FROM ITALY.

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Abstract

This paper investigates the impact of space procurement on supplier firms. We empirically study how public procurement affects several dimensions of firms' performance in the Italian space industry. Our research strategy implies hypothesis-validating interviews, a survey, and an econometric analysis. We found space procurement to generate two outcomes in firms: "intermediate outcomes" - i.e., learning, innovation, and market penetration - and "final outcomes" - i.e., profit and sales, business development, and employment – with the former inducing the latter. Our results offer insights for understanding the role of public procurement from the suppliers' perspective.

Keywords: Public procurement, innovation, space economy, space industry, buyer-supplier relationship.

JEL Codes: C25, H57, O32, O38

1. Introduction

Innovation related to public procurement is a prominent issue in the academic debate and in the practice of policymakers. Scholars have largely investigated the rationalities and scope of public procurement, aiming at the diffusion of innovation for "transformative change" (e.g., Schot and Steinmueller, 2018; Uyarra et al., 2020) and societal goals (Edler and Georghiou, 2007; Edquist and Zabala-Iturriagagoitia, 2012, 2015). From the perspective of practitioners and policymakers, the interest is growing in the direction of mission-oriented, demand-side innovation policies that use public procurement as an innovation lever (Mazzucato, 2018; Crespi and Guarascio, 2019; Caravella and Crespi, 2020). Public procurement of innovation drives suppliers to meet the requirements of an administration in the direction of innovative solutions to societal problems, thereby envisaging "public demand as an engine for innovation" (Edler and Georghiou, 2007, p. 952). Besides, public procurement brings together a public purchaser – the procurer agency – and one or more firms – the suppliers – laying the ground for a relationship between them. While emphasis is usually placed on the result of this interaction in the form of the innovation required in the procurement agreement, most of what happens during the process is neglected and underestimated. The procurement relationship pushes firms to acquire new knowledge, explore new technical solutions, and search for new collaborators; in a later stage, it can produce innovation that spreads into firms' products and services, eventually reaching new clients and opening new markets. The benefits of the procurement relation may return to the firms in the form of better economic performance in terms of sales and profits, further development in the firms' business, such as the opening of new production lines leading to alternative uses of products and services to serve new markets (Autio et al., 2003, Autio, 2014; Florio et al., 2018; Castelnovo and Dal Molin, 2021).

In this paper we explore the effects of public procurement to elucidate their nature and occurrence and to understand their impact on firms' performance. We consider the suppliers to gain benefits in the procurement relationship in the form of intermediate and final outcomes, with the former impacting on the latter. We found a gap in the literature with regards to the complex implementation of public procurement, that overlooks the impacts of the purchaser-supplier interaction, especially considering how the research predominately adopts the procurer's perspective (Obwegeser and Müller, 2018), giving little or no importance to what suppliers gain during the relationship.

We focus on the space sector to investigate this gap and answer our research questions about the impact of public procurement on firms' performance. The reason can be found in the growing importance of this industry for the world economy, beyond its role in the generation of innovation and the huge importance of public procurement for space firms and space-related technologies. Global expenditure in space activities has recently reached 75 billion dollars (62.8 billion euros), the highest figure so far, and the upwards trend continues (OECD, 2019: 13). The space industry in Europe has reached its maximum commercial value in recent years, with more than 8 billion euros in sales and 40 thousand employees; public purchasers are responsible for around 60% of total sales, with the European Space Agency (ESA) being the most important (ASD, 2019). In terms of investment, France is the first European space economy with spending equalling 0.1% of GDP, followed by Italy at 0.05% and Germany at 0.047% (OECD, 2019).

European space is experiencing changes due to both internal and external factors (Mazzucato and Robinson, 2017). Internally, and at a time of tightening budgets, European space agencies are required to prove the economic return of their actions, for example, by connecting upstream activities at the core of their competencies, such as space exploration, to downstream applications, from the creation of new technologies to products and services for use in other sectors with different purposes (ESA, 2009, 2020). Identifying and quantifying the economic benefits generated to society by capital-intensive scientific projects has become increasingly relevant. For instance, Graziola et al. (2009), in a study commissioned by the ASI, showed that the aerospace industry generates positive externalities to other economic sectors. The results of their econometric analysis revealed that the innovative activities carried out in the aerospace industry enhance the value added and productivity of rest of the manufacturing industry in Europe. The role of technology transfer is often crucial to generate positive technological spill-overs. Scalia and Bonventre (2020) provided evidence of technology transfer (TT) of nanomaterials and nanostructures developed for space missions and programs to other fields like, e.g., energy conversion, power generation, storage systems, and electronics (for a systematic review of the Space TT literature see Venturini and Verbano, 2014).

Externally, the European space industry must keep pace with the rapid technological change and competitive pressure in a global market dominated by traditional players such as the USA and Russia, and emerging powers as China and India. In this context, the literature on the procurement of science organizations (Autio et al., 2004; Autio, 2014; Robinson and Mazzucato, 2019; Bastianin and Del Bo, 2020) offers valid insights into the way in which such organizations act as risk takers, reducing suppliers' perceived risk in undertaking complex projects and giving initial stimuli to firms' innovation.

In all countries, public procurement has been fundamental for the development of the space industry, particularly in Europe, as a key ingredient of innovation policies (Landoni and Ogilvie, 2019). In this respect, Italy is a prominent case. The Italian space economy and industry is the third largest in Europe and the seventh in the world according to OECD (2019). The Italian space industry includes large and small-medium enterprises that are active in every stage of the space economy (Landoni, 2020), from manufacturing large sections of the International Space Station (ISS) to mapping tectonic areas prone to earthquakes by using images from the Copernicus Sentinel-1 satellites (ESA, 2016). The expertise and technological level of the Italian space industry is the result of a demand-side innovation policy based on public procurement and implemented by the Italian Space Agency (Petroni and Verbano, 2000; Landoni, 2016, 2017, 2018).

Our aim is to further understand the overall impact of public procurement on firms. We offer an analysis of the Italian space industry because of the relevant role of space procurement in Italy. Our research question arises from the lack of understanding of the purchaser-supplier relationship, the underestimation of public procurement outcomes, and how these outcomes impact firms' performance. Based on the results of our study, we suggest implications for theory and policymaking.

Our paper contributes to theory in two ways. First, it sheds light on the mechanisms generated by the procurement relationship between industrial firms and public space agencies; in detail, we identified three intermediate outcomes accruing to supplier firms', namely learning, innovation, and market penetration. Second, these intermediate outcomes have a cascade effect on firms' economic and social performance in terms of an increase in sales, profits, employment, and business development.

The paper is structured as follows. The next section provides a theoretical framework of our research hypotheses. The third section presents our research design based on a mix of methods that include hypotheses-validating in-depth interviews, a descriptive analysis based on survey answers, and an econometric using implying ordered logit models. The fourth section reports the results of the study. The last section concludes with a discussion of our results and the contributions to the theory. We eventually report the limitations of our research and directions for future research, and discuss implications for practitioners and policymakers.

2. Theoretical Background

2.1 Public procurement as an innovation lever

Demand for innovation is a powerful incentive and sometimes a necessary condition for investing in innovation (Iammarino et al., 2009; D'Este et al. 2012; García-Quevedo et al., 2016). Therefore, policies aimed at fostering innovation have mainly acted on the demand-side to trigger innovative activities (Edler and Georghiou 2007; Georghiou et al. 2014). One of the most important instruments for a demand-side innovation policy is public procurement (Uyarra and Flanagan 2010; Filippetti and Archibugi 2011; Edquist 2015; Ghisetti, 2017; Mazzucato and Kattel 2018).

Public procurement, however, does not always imply innovation; for innovation to be properly incentivized, public procurement must combine the reduction of uncertainty about market demand with information about future needs (Guerzoni, 2010; Åberg and Bengtson, 2015; Edquist and Zabala-Iturriagagoitia, 2015), which consist in requirements and purchasing contracts. This is the case when a source of procurement, e.g. a public agency, places an order for a product or a service that does not exist at the time, but which could probably be developed within a reasonable period (Edquist and Zabala-Iturriagagoitia, 2012). Innovation, in this case, may correspond to a formal requirement in the procurement contract, but whether innovation is a formal requirement or not, (public procurement for innovation (PPI) as opposed to the regular type) innovation may happen regardless, as either a direct result or a side effect of procurement (Edquist, 2015). PPI consists in the purchase, by competitive tender, of a product or service to be developed in the future. The mix of obligations and incentives together with a clear market need and future demand creates the conditions for investing in innovation (Landoni, 2017: 585; Florio et al., 2018).

The literature about PPI has grown extensively, especially since the seminal article by Edler and Georghiou (2007). Numerous studies have discussed definitions, rationalities, and effects (Obwegeser and Müller, 2018; Uyarra et al., 2020). These studies span from case-studies (Edquist et al., 2015; Landoni, 2017; Grillitsch et al., 2019) to quantitative analyses (Guerzoni and Raiteri, 2015; Georghiou et al., 2014; Castelnovo et al., 2018; Florio et al., 2018; Raiteri, 2018; Caravella and Crespi, 2020; Divella and Sterlacchini, 2020). On the one hand, case-studies have provided insights about the means and processes of PPI; on the other, quantitative analysis, based on large datasets, have empirically measured its outcome. A gap in this literature stream lies with the difficulty of bridging a clear understanding of the process of procurement at a deeper level of analysis (other than at the national level), such as the firm and the industry level. Still, despite the large number of studies, the role of the public sector in shaping demand conditions for innovation is barely acknowledged (Gee and Uyarra, 2013; Uyarra et al., 2020), as well as its importance for the creation, structure, and access to new markets (Bleda and Chicot, 2020; Willman, 2020).

2.2 Intermediate outcomes of public procurement

The public role is even more important when a market does not exist beside the demand generated by the procurement. That is often the case of complex, risky, or costly technologies, as well as single-use technologies. For example, the standard mission-oriented innovation policies that target *moonshot innovation*, in the sense of ambitious and ground-breaking projects, such as the Apollo program that put a man on the Moon. The technologies developed in the Apollo program had no market other than the public, the US Government and NASA, and had barely any market value. Yet, the transfer of technology from NASA to market applications is evident regardless of the original aims of the procurement contract (Doctors, 1971; Chakrabarti and Rubenstein, 1975; Bozeman, 2000; Mazzucato and Robinson, 2018; Robinson and Mazzucato, 2019).

The same thing happened for ESA (2009). By surveying companies in the ESA supply chain over the years 2000−2007, the Danish Agency for Science (2008) shows that every million euros of Danish contributions to ESA generated 4.5 million euros via the direct increase of ESA suppliers' turnover and indirect outcomes from the development of new technologies and competencies. This means that innovation goes beyond what was initially formally required by the procurement contract and appears indirectly as a side effect, for example, public procurement might induce R&D investments by new or additional firms or increase the share of innovative turnover.

The aforementioned literature fails to comprehend and underestimates the innovation mechanisms that produce improvements in the supplier firm performance beyond the requirements of the procurement contract. While the focus is on the so-called *final outcomes*, including increased sales, profits, level of employment and reduced costs, the generative mechanisms behind them are disregarded. The literature on the procurement of science organisations that operate large-scale research projects and infrastructures (Schmied, 1987; Nordberg et al., 2003; Autio et al. 2004; Florio et al., 2016; Willman, 2020) refers to these sort of mechanisms, and more recently Florio et al. (2018) labelled as *intermediate outcomes* those consisting of learning, innovation, and market penetration that result from the relation with the source of procurement, in our case, a space agency.

Learning outcomes occur when the complexity of the order encourages the supplier firm to interact with the contracting organisation for knowledge exchange and technological learning, thereby spurring innovation in industrial firms through this channel (Lundvall, 1993; Edquist, 2011; Cano-Kollmann et al., 2017). Innovation outcomes refer to the development of innovative products or processes introduced by the supplier with the aim of matching the procurement requirements. Lastly, market penetration points to the acquisition of new clients and to more general market benefits stemming, for instance, from the increased reputation that comes from being a supplier to a science organisation, i.e., a public agency. In the case of world-renowned public agencies such as NASA and laboratories such as the CERN (Autio et al., 2004; Florio et al., 2018), it has been shown that firms exploit the science organization as a marketing reference for other potential customers in the market and thus improve their competitiveness and innovativeness thanks to a certification effect (Dai et al., 2020).

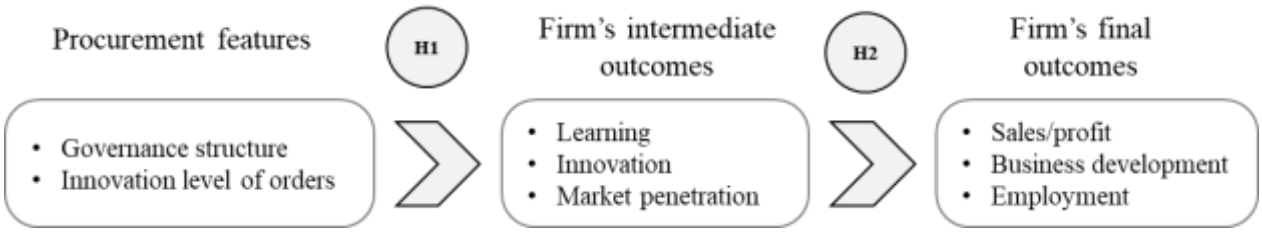
In this regard, the relationship that space agencies and supplier firms put in place to manage the procurement contract is a key factor to consider in our conceptual framework. The governance structure of this relationship defines the level of stability of technological and scientific interactions, support, and the degree of collaboration. The PPI literature sees procurement as a driver of innovation thanks to the flow of information and interactions among economic actors during project implementation (Edquist and Zubala-Iturriagagoitia, 2012; Georghiou et al., 2014). The notion of *governance structure* of the procurement relationship lies in this stream of literature. In our case, *governance structure* refers to the modes of interaction between the public purchasers (i.e., the space agency) and the firms (the suppliers) as a mediating factor of intermediate and final outcomes pertaining to the supplier firm.

The interaction of procurer and supplier is linked to the level of innovation in the procurement orders, based on the degree of technological novelty and uncertainty. Technological novelty and uncertainty are among the main reasons for industrial collaboration, allowing firms to develop cumulative learning processes based on technological know-how and seize external opportunities by means of absorptive capacity (Cohen and Levinthal, 1990; Spithoven et al., 2010). Accordingly, the occurrence of both intermediate and final outcomes is mediated and shaped by these two factors: the *governance structure* of the procurement relationship and the *innovation level* of the order.

2.3 Hypothesis development

This paper aims to fill in the above-mentioned gap in the literature. Specifically, the objectives are to understand whether – beyond the activities foreseen by the procurement contract – the relationship with a source of procurement in the space sector generates intermediate outcomes, and to assess how they affect the firm's performance (final outcomes). In particular, we look at how the procurement relation between space agencies and industrial firms in Italy impacts the performance of supplier firms beyond expected procurement results by means of intermediate outcomes in the form of learning, innovation, and market penetration. We translate our goal into two testable research hypotheses, which are reflected in our conceptual framework in Figure 1.

Figure 1. Conceptual framework



Source: Authors' elaboration

First, we look at whether and how the procurement relationship with a space agency, defined in terms of governance structure and innovation level of the order in the procurement contract, affects the emergence of intermediate outcomes.

- H1: *Public procurement generates intermediate outcomes (learning, innovation, and market penetration) to the suppliers of space agencies.*

We then considered the intermediate outcomes of public procurement to positively impact on the supplier firms' economic and social performance indicators, which result in more sales, increasing profits, business development, and increased employment, among others.

- H2: *Intermediate outcomes positively affect the economic performance (the final outcomes) of the supplier firms.*

3. Methods

3.1 A three-step mixed method analysis

Our empirical strategy combines qualitative and quantitative research methods. Mixing methods ensures that the results are a methodological artefact (Burke et al., 2007). Specifically, the methodology consists of three main steps, which complement each other. First, we performed the semi-structured interviews to a sample of selected firms explore, test, and validate our hypothesis; furthermore, we collected anecdotes and first-hand evidence of the mechanism of the outcomes generation we were exploring. Second, we administrated the survey to a wider sample of industrial suppliers to verify and confirm the existence of intermediate and final outcomes as result of the procurement relationship. Lastly, the econometric analysis helped us to understand the impact of the intermediate outcomes on the final ones, and how this effect is mediated by the governance structure and firms' characteristics. The description of each step is provided in the following sub-sections.

3.2 Conducting semi-structured interviews

With the aim of testing the validity of our hypothesis and refining the terms in our conceptual frameworks, we preliminary screened the sample for a set of cases that included firms from all areas of the country (North, Centre, South), ages, sizes (small, medium, large), and ownership types (private or state-owned). This sampling strategy aimed to achieve a significant range of variation over a set of dimensions related to procurement features and supplier characteristics (Eisenhardt, 1989).

We performed semi-structured interviews by phone with ten Italian space firms between the end of 2019 and February 2020. The process was conceived with the objective of exploring cases of firms that had the potential to provide interesting insights into their possible long-term outcomes, both intermediate and final ones.

We put effort into reaching individuals who had control of public procurement contracts within the firm to understand: (i) what type of relationships were put in place between the space agency and the suppliers during the project's execution (governance structure); (ii) how the relationships evolved and shaped intermediate outcomes (learning, innovation, market penetration) during the process (intermediate outcomes); and (iii) the impact of those outcomes generated by the procurement relationship and to what extent it impacted on the firms' economic performance (final outcomes). Thanks to these in-depth interviews, we were able to document intermediate outcomes that impacted companies even when not formally specified in the procurement contracts.

The interviews were used to validate, refine, and document our research hypothesis, and also to inform the design of the survey, which represented our second step.

3.3 Implementing the survey

Based on our conceptual model, we structured the questionnaire in three main sections: (i) the relationship between the respondent supplier and the contracting space agency; (ii) the impact of the procurement on the supplier's performance as perceived by the supplier. In this section, both the intermediate and the final outcomes were investigated; (iii) the relationship between the supplier industrial firm and its subcontractors, i.e., the second-tier suppliers. Companies were asked to reply to both closed-ended questions and five-point Likert scale questions to detect to what extent they agreed or disagreed with a specific statement.[1]

The target population of the survey embraced Italian firms operating in the space sector. With the support of ASI, we identified the population of firms involved in the ASI supply chain relying on various sources, since it is not possible to identify firms operating in the space industry based on an existing classification (e.g., the ATECO, NACE, or comparable industry classifications). The sources we employed are the ASI procurement database (extracted from Archimede[2]), the ESA supplier

[1]Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (Text with EEA relevance).

[2] Archimede is the web platform used by ASI to manage the contracts awarded by ASI to its contracting parties. It reports information on legal, economic, and accounting specifications.

portal, and the list of firms belonging to space industry associations[3]. Overall, we identified and invited to the survey 854 firms for which we were able to find a contact detail (email or phone). 112 firms answered the survey. Although accounting for a low percentage of our targeted sample (13%), these respondents represent the major recipients of ASI contracts.

The online survey was run between January and May 2020 through CAWI and periodically supported by phone and email reminders (sent every month) to guarantee a satisfactory number of valid answers.

3.4 Performing the econometric analysis

We used ordered logit models to test our second research hypothesis, with suppliers' performance (final outcomes), variously measured, as the dependent variable. The aim of the econometric analysis was to determine correlations between suppliers' final outcomes and their determinants as suggested by the PPI literature, with a specific focus on the impact of the intermediate outcomes. Starting from the items included in the survey, we built a set of variables to be used in the econometric analysis measuring the suppliers' intermediate and final outcomes, as well as the variable describing the kind of relationship established.

Since the suppliers' performance variables of interest are ordinal variables, to test our hypothesis we estimated ordered logit models (see e.g., McCullagh, 1980 and Greene, 2012). For the generic *j*th value assumed by the outcome variable Y_i, ordered logit models take the form:

$$Pr(y_i = j|\mathbf{X}_{ic}) = \Lambda(\mu_j - \mathbf{X'}_{ic}\boldsymbol{\beta}) - \Lambda(\mu_{j-1} - \mathbf{X'}_{ic}\boldsymbol{\beta}) \quad (1)$$

where *i* =1, …, N denotes the *i-th* firm, Λ is the cumulative distribution function of the standard logistic distribution and the parameters μ are unknown thresholds to be estimated together with $\boldsymbol{\beta}$. According to the conceptual framework, the variable Y_i is one of the final outcomes *Sales/Profits*, *Business Development* or *Employment*. The vector of regressors $\mathbf{X}_{ic}$ includes: i) intermediate outcomes; ii) a variable describing the governance structure of the procurement relationship; iii) firm's characteristics used as controls.

[3] Italian Space Agency virtual district; Association for Space-based Applications and Services (ASAS); Associazione delle Imprese per le Attività Spaziali/Italian space companies and activities association (AIPAS); Federazione Italiana per l'Aerospazio, la Difesa e la Sicurezza/Italian federation of aerospace, defense, and security (AIAD); LazioInnova.

4. Analysis and results

4.1 Hypothesis-validation interviews

The interviews returned insights that were consistent with our hypothesis. We found that firms involved in space procurement experienced intermediate outcomes, i.e. learning, innovation, and market penetration outcomes. We also asked companies about how intermediate outcomes impacted on their final economic performance. For example, an interviewee firm reported that "certainly, we have developed all our innovative products with ASI and ESA"; while in terms of learning, another firm declared to "have developed a big data capability". In another case, the interviewee declared that the result of the procurement process "has been used for other clients, including ESA and private companies in Italy and abroad". Similarly, a further firm confirmed the existence of reputational effects, "no one who is unable to sign a contract in their own country would find a client abroad. Clearly, a contract with ASI is a good introduction".

On top of that, interviews reveal that outcomes are not limited to first-tier suppliers, but interviews indicate that learning, innovation, and market penetration outcomes spread to their sub-contractors, and therefore through the entire space supply network. According to a firm, the space agency "is a promoter of a business network, it helps companies and markets to communicate". This evidence is not new and other studies investigating the public procurement of other big-science organisations operating in other fields corroborate it (Nordberg et al., 2003; Autio et al., 2004; Florio et al., 2018).

Table 1 Overview of the selected case-studies

Firm name	Main products commercialized	Area (City)	Size of employment	Year of activity	Type	Length and intensity of the collaboration	Main intermediate outcomes	Main final outcomes
Alenia Spazio	Space manufacturer	Centre (Rome)	Very large	1990-2004	State-owned (Leonardo)	More than 15 years - Systematic	Learning; Innovation; Market penetration	Business development; employment
Altec	Logistic technology engineering	North (Turin)	Small	2001-ongoing	State-owned	More than 15 years - Systematic	Learning; Innovation; Market penetration	Business development
Argotec	Small satellite engineering	North (Turin)	Small	2008-ongoing	Joint Venture ASI & TAS	5 years - episodic	Innovation	Sales
AVIO	Launcher	Centre (Rome)	Very large	2006-ongoing (origin in 1912)	Private	More than 15 years - Systematic	Learning; Innovation.	Business development
CGS	Space systems integration	North (Milan)	\	1987-2009	Private	More than 15 years - Episodic	Learning; Innovation.	Business development
OHB Italia	Space systems integration	North (Milan)	Medium	2017-ongoing	(Leonardo 30%)	10 years - episodic	Learning; Innovation.	Business development and employment
Planetek	Geospatial data services	South (Bari)	Small	1994-ongoing	Private (acquired)	More than 25 years - Systematic	Learning; Innovation; Market penetration	Business development;
(TAS) Tales Alenia Space	Space manufacturer	Centre (Rome)	Very large	2007-ongoing (origin in 1990)	Private	More than 10 years - Systematic	Learning; Innovation; Market penetration	Employment
Telespazio	Space services	Centre (Rome)	Large	1961-ongoing	Private	More than 25 years - Systematic	Learning; Innovation; Market penetration	Business development and employment

Firm name	Main products commercialized	Area (City)	Size of employment	Year of activity	Type	Length and intensity of the collaboration	Main intermediate outcomes	Main final outcomes
Vitrociset	Logistic technology engineering	Centre (Rome)	Medium	1971-ongoing	State-owned	More than 25 years - Systematic	Learning; Innovation; Market penetration	Business development and employment

Source: authors' elaboration. Small: <50; 51<medium <100 ; 101<large<999 ; 1.000<very large.

4.2 Descriptive statistics

We collected 112 completed questionnaires out of a target population of 854 contacted companies. Respondents represent 13% of the target population but account for 86% of the total volume of procurement activities undertaken between 1987 and 2018 by the Italian Space Agency, by far the most relevant public procurer for Italian firms in the domestic market. This assures us regarding the relevance of the firms covered by the survey but also rises concerns about a possible selection problem that may bias our results. To be sure that the sample of respondents is representative of the firms operating in the Italian space industry, we compared its composition with that of the target population of 854 firms. To this aim, we sourced information on firms' size and activity sector (based on the NACE 2-digits classification) from the Orbis database[4]. As highlighted by figures A.1 and A.2 in the appendix, respondent firms are comparable to the target population both in terms of dimension and economic activity, except for two sectors, which are over-represented among respondents (M-72: "Scientific Research and Development" and M-74: "Professional, Scientific and Technical Activities").

47% of our respondents are in the Centre of Italy, 36% in the North and 17% in the South. They are mainly small-sized firms (74% of the sample), while medium and large supplier firms represent 12.5% and 13.5% respectively. Nearly half of the respondents operate in the fields of research and development (NACE M-72) and the production of ICT systems and related activities (NACE J-62) (26% and 21% respectively). The remaining part of our sample operates in different sectors mostly including production of computers, optical, and electronic products (NACE C-26); telecommunications and broadcasting activities (NACE J-60), and other consulting, scientific and technical activities (NACE M-74). Respondents reported on average 24 years of activity in the space sector (years of experience ranges from 1 to 60 years) and for 24% of them, the turnover related to the space sector – over the last three years - is in the range of 91-100%.[5]

Following the conceptual model, we asked about the innovation level of products and services delivered to the space agency, on the interaction modes between the firm and the agency for managing the project execution as well as the outcomes achieved by the firm thanks to the procurement activities.

We investigated the innovation level by asking about the technological readiness level (TRL) of the services and products provided.[6] Table 2 shows the share of respondents according to the TRL of the supplied products and services. Most of orders have an innovation level between TRL 4 and TRL 9, i.e., technologies in testing phases in laboratories or industrial and operational environments. Put differently, supplied products either required significant customization, technological development, or cutting-edge/enabling technologies. In contrast, the share of companies processing orders that entail the formulation of technological concepts or observation of basic principles (TRL 1 - TRL 3) is lower.

Table 2 Technology readiness level (TRL) of the services and products provided

We delivered products/services with the following TRL:	N (share) of respondents selecting the options 'often' and 'always'
TRL 1 – Basic principles observed	19 (23%)
TRL 2 – Technology concept formulated	21 (24%)

[4] https://www.bvdinfo.com/en-gb/our-products/data/international/orbis

[5] 57% of respondents recorded a turnover related to the space sector of less than 50%, while for the remaining 19% of respondents it varies from 50% to 90%.

[6] TRLs are indicators of the maturity level of particular technologies and provide a common understanding of a specific technology status along the innovation chain. There are nine technology readiness levels; TRL 1 being the lowest and TRL 9 the highest. Developed by NASA in the 1970s, the Technology Readiness Levels (TRLs) are a method for estimating the maturity of technologies during the acquisition phase of a program. The TRL classification is used today at international level, including by ESA and the European Commission to indicate the maturity level of particular technologies, for instance in the H2020 programme.

https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-ga_en.pdf (pg. 27).

TRL 3 – Experimental proof of concept	30 (34%)
TRL 4 – Technology validated in laboratory	37 (41%)
TRL 5 – Technology validated in relevant environment (industrially relevant environment)	35 (41%)
TRL 6 – Technology demonstrated in relevant environment (industrially relevant environment, earth, or space)	39 (44%)
TRL 7 – System prototype demonstration in operational environment (space environment)	38 (42%)
TRL 8 – System complete and qualified	35 (41%)
TRL 9 – Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)	33 (37%)

Note: 112 respondents. Multiple-choice questions. Respondents were asked to indicate their answer on a scale ranging from "Never" (0% of orders) to "Always" (100% of orders)

Regarding the governance structure of the procurement relationship, it was detected by designing specific questions on how the supplier and the space agency interact during the procurement relationship. Table 3 shows that 58% of surveyed firms established close and stable interactions with the space agency during the procurement relationship, while 55% always try to find a solution when difficulties arose instead of insisting on contractual clauses.

Table 3 Governance structure: specific aspects of the procurement relationship

During the procurement phase with the space agency…	N (share) of respondents selecting the options 'often' and 'always'
Our firm and the space agency had close and stable interactions to address scientific and technical issues	65 (58%)
During unexpected situations, our firm and the space agency dialogued to reach a solution without insisting on contractual clauses	61 (55%)
Our firm received technical and scientific support from the space agency	44 (39%)
Our firm faced technological and scientific challenges because of the project complexity	10 (9%)

Note: 112 respondents. Multiple answers question. Respondents were asked to indicate their answer on a scale ranging from "Never" (0%, it never happened) to "Always" (100% - it always happened)

In addition to the above information, and more importantly for our purpose, we asked respondents about the impact that the procurement relationship with the space agency had on their firm (Table 4). In terms of *process innovation*, 90% of respondents stated that thanks to the relationship with the space agency, they increased their technical know-how; 71% improved their R&D capabilities, while 62% improved their management/organisational capabilities. In addition, more than 50% of suppliers declared improved production processes.

The positive impact on the process innovation was also accompanied by *an innovation in the products and services*. 76% of respondents reported that they improved the quality of products and services, while new technologies were introduced by 63% of respondents, followed by the introduction of new products (55%) and services (48%). In comparison, a limited impact (22% of respondents) was observed in terms of spin-off projects launched.

The procurement relationship is also likely to boost *market penetration*. 86% of respondents improved its credibility as suppliers, 59% increased the number of clients, while 56% acquired new knowledge about market needs and trends. New customers were either other firms in the space sector (59% of respondents) and research institutes (50%), or other space agencies (35%) either based in Italy or abroad.

The survey's answers seem to support our research hypotheses: intermediate innovation outcomes and market penetration are likely to lead to improvements of suppliers' economic performance (final outcome) thanks to the work carried out for the space agency (Table 4). 75% of respondents reported that thanks to the procurement acquisition, they increased total sales, or established a new R&D (50%) or business team/unit (29%). Our sample also confirms a positive impact on employment: 47% of respondents increased the number of employees with a permanent contract following the relationship with the space agency. Concerning financial performance, respondents confirmed an increase in profits (38%) and a reduction in costs (12%). There are a few cases that reported financial loss (9%) and very few that risked bankruptcy due to failing to match the procurement requirements (4%). This can be interpreted as being caused by a change in behaviour in public administration towards more risk-taking innovation, in line with good innovation policies (Rodrick, 2004; Robinson and Mazzucato, 2019).

Table 4 - Outcomes of the procurement relationship

Learning *Thanks to the contract with the space agency, we…*	Agree	Neutral	Disagree
improved technical know-how	90%	6%	4%
improved R&D capabilities	71%	21%	8%
improved management/organizational capabilities	62%	28%	11%
acquired new knowledge about market needs and trends	56%	30%	13%
Innovation *Thanks to the contract with the space agency, we …*	Agree	Neutral	Disagree
developed new technologies	63%	23%	13%
developed new products	55%	26%	19%
developed new services	48%	29%	22%
improved the quality of products and services	76%	21%	4%
improved production processes	54%	33%	13%
developed a new patent or trademark	23%	30%	46%
Market penetration (1) *Thanks to the contract with the space agency, we…*	Agree	Neutral	Disagree
improved credibility as supplier	86%	10%	4%
increased the number of clients	59%	22%	19%
Market penetration (2) *Thanks to the contract with the space agency, we acquired new customers, specifically…*	Agree	Neutral	Disagree
firms in the space sector	59%	21%	20%
firms in Italy	52%	25%	23%
research institutes	50%	26%	24%
firms in other countries	47%	25%	28%
other space agencies	35%	36%	29%
firms in another sector	26%	38%	36%
Socio-economic performance *Thanks to the contract with the space agency, we…*	Agree	Neutral	Disagree
increased total sales	75%	14%	11%
increased overall profitability	38%	40%	21%
established a new R&D team/unit	50%	23%	27%
established a new business unit	29%	32%	38%
entered a new sector	45%	25%	30%
spin-off projects	22%	38%	39%
reduced production costs	12%	41%	47%
experienced some financial loss	9%	20%	71%
faced risk of bankruptcy	4%	14%	82%
increased the number of employees with a permanent contract	47%	29%	24%
increased the number of employees with a temporary contract	34%	29%	37%

Note: 112 respondents to each question. Respondents were asked to indicate their answer on a Linkert scale including 5 options (disagree, partially disagree, neutral, partially agree, agree). In the table, the option "Agree" groups the original options "partially agree" and "agree" while "Disagree" groups the original options "partially disagree" and "disagree".

In the last part of our survey, we asked respondents to indicate whether they mobilized any subcontractor to carry out their order(s) for the space agency, and, if so, which type of outcome (if any) subcontractors benefitted because of the procurement activity. 62 respondents (55%) mobilised a subcontractor in the delivery of their order(s), while the remaining 50 firms already had the necessary competencies in-house. Relevant experiences in Italian/European space supply chain, as well as trust developed during previous contacts, were the most reported means for selecting these partners. Table 5 shows that, according to the perception of 73% and 65% of respondents respectively, subcontractors may have increased their technical know-how or innovated their own products and processes thanks to the work carried out in relation to the order delivered to the space agency. This suggests that the positive effects generated by upstream activities, such as procurement, are not limited to the first-tier relationships, but are likely to spread out along the entire supply chain (George, 2019).

Table 5. Outcomes accruing to second-tier suppliers as perceived by first-tier (N= 62).

Process innovation *Thanks to the procurement order provided for the Space Agency, our subcontractors...*	**Agree**	**Neutral**	**Disagree**
increased technical know-how	73%	21%	6%
innovated products or processes	65%	29%	6%
improved production process	44%	48%	8%
attracted new customers	39%	55%	6%

Note: 62 Respondents. They were asked to indicate their answer on a Linkert scale including 5 options (disagree, partially disagree, neutral, partially agree, agree). In the table, the option "Agree" groups the original options "partially agree" and "agree" while "Disagree" groups the original options "partially disagree" and "disagree".

4.3 Econometric results

While the questionnaire results are interesting in their own right, we resort to order logistic models (Eq.1) to test our second research hypothesis and find statistical regularities amongst surveys answers, and specifically, between the intermediate and final outcomes of suppliers. The econometric exercise finalises our methodology.

We pre-treated the survey answers to obtain the variables entering in the econometric models. Table 6 gives an overview of the variables, which, consistently with our conceptual framework, were classified by clearly distinguishing the intermediate outcomes, the final outcomes, and the governance structure. The TRLs, along with other control variables, were properly accounted for as well. Column 1 lists the item as reported in the survey (and in the descriptive analysis); Column 2 shows the variable codification, while Columns 3, 4 and 5 reports the mean, the maximum and minimum of the variables respectively.

The variable *Governance structure* describes the procurement relationship established between the space agency and the supplier. This indicator was obtained from Table 3 as the sum of three dichotomous variables indicating whether the supplier: i) established close and stable relations with the space agency to discuss technological and scientific issues during the procurement activity; ii) received technological and scientific support from the space agency; iii) set up a productive dialogue with the space agency in case of unexpected situations and achieved a solution without making use of contractual clauses. The indicator ranges from 0 (none of the options chosen) to 3 (all options chosen). Hence, higher values of the indicator should capture the establishment of a purchaser–supplier relationship based on close cooperation and mutual reliance to reach the intended goal (Gereffi, 2005; Williamson, 1991).[7]

Intermediate outcomes are meant to capture changes in firms' learning, innovation and market penetration due to the collaboration established with the space agency. The indicators we used to measure intermediate outcomes are defined as follows:

- the variable *Learning* captures changes in firms' technical, managerial and market knowledge. It is built as the sum of four binary outcomes, using equal weights: "improved technical know-how", "improved R&D capabilities", "improved managerial and organizational capabilities" and "acquired new knowledge about market needs and trends". The variable ranges from 0 (no learning outcomes) to 4 (learning outcomes in each item).

[7] By using the Gereffi's (2005) definition, who in turn elaborates on Williamson (1991), a "Relational governance" implies that buyer and supplier cooperate regularly to deal with complex information that is not easily transmitted or learned. As a consequence, frequent interactions and knowledge sharing take place to remedy the incompleteness of contracts, and flexibly deal with all possible contingencies. Relational governance consists of linkages that take time to build and that generate mutual reliance, so the costs and difficulties of switching to a new partner tend to be high.

- the variable *Innovation* measures improvements in firms' innovation capacity and it is the sum (with equal weights) of six binary items: "new products", "new services", "new production processes", "new technologies", "new patents and trademarks" and "increased product and service quality".

- the variable *Market penetration* is obtained as the sum of the two binary items "acquisition of new clients" and "improved image and reputation", as the space agency acts as a marketing reference for the supplier.

The *final outcomes* we are interested in are sales/profits, business development and employment. Specifically:

- the variable *Sales/Profits* measures suppliers' performance in terms of financial results. It is built as the sum of two binary items with equal weights: "increased total sales" and "increased overall profitability".

- the variable *Business development* aims to capture suppliers' development activities and it is the sum (with equal weights) of four binary items: "established a new business unit", "established a new R&D team/unit", "spin-offs projects", "entered a new sector".

- the variable *Employment* is constructed as the sum of the two binary items: "increased the number of employees with a permanent contract" and "increased the number of employees with a temporary contract".

In addition to the above variables, we also added a set of covariates to check whether the outcomes differ according to the firm's characteristics or the innovation level of the order. This set of additional variables includes:

- The variable *TRL* describing the Technological Readiness Level of the product or service delivered, which is a continuous variable ranging from 0 to 9;

- The dummy variable *High-tech* that takes a value of 1 if the supplier is active in high-technology, medium-high technology or high-tech knowledge intensive services sectors according to the Eurostat indicators on high-tech industry and knowledge[8], and 0 otherwise;

- the continuous variable *Age* that measures supplier age;

- the continuous variable *Years in the space industry* indicates how many years the supplier has been active in the space industry;

- the dummy variable *Revenues from space sector* takes the value of 1 if the share of revenues from space activities is greater or equal to 70% of the supplier's total revenues;

- the set of dummy variables *Size* classifies firms into four categories according to their number of employees (micro<10, 10≤small<50, 50≤medium<250 and 250≤large);

- the set of dummy variables *Geographical Area* accounting for firms' geographical location (North, Centre or South of Italy);

- the set of dummy variables *Sector* specifies the sector in which the firms operate, according to the NACE two-digits classification.

Table 6. Econometric analysis: list of variables

(1)	(2)	(3)	(4)	(5)
Survey items	Codification (label)	Mean	Min	Max
Close and stable cooperation with the space agency to discuss technological and scientific issues during the procurement activity	**Governance structure**	1.52	0	3
Received technological and scientific support from the space agency				
Set up a productive dialogue with the space agency in case of unexpected situations and achieved a solution without making use of contractual clauses				

[8] https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an3.pdf

Intermediate outcomes				
Improved technical know-how	**Learning**	2.79	0	4
Improved R&D capabilities				
Improved management and organizational capabilities				
Acquired new knowledge about market needs and trends				
New products	**Innovation**	3.20	0	6
New services				
New production processes				
New technologies				
Patents and trademarks				
Increased product and service quality				
Acquisition of new clients	**Market penetration**	1.45	0	2
Improved image and reputation				
Final outcomes				
Increased total sales	**Sales/Profits**	1.13	0	2
Increased overall profitability				
Established a new business unit	**Business development**	1.46	0	4
Established a new R&D team/unit				
Spin-offs projects				
Entered a new sector				
increased the number of employees with a permanent contract	**Employment**	0.81	0	2
increased the number of employees with a temporary contract				
Additional variables				
Technological Readiness Level (TRL)		5.52	0	9
High Tech			0	1
Age		24.13	3	112
Years in the space industry		15.9	1	61
Revenues from space sector		0.34	0	1
Size			0	1
Geographical Area			0	1
Sector			0	1

Table 7 provides estimated results of the three ordered logit models considered, one for each of the final outcomes: sales/profits, business development and employment. Column 1 presents the estimated coefficients of the model where *Sales/Profits* is the outcome of interest. Innovation and market penetration are the main drivers for suppliers' economic performance. Both the development of new products/services and reputation effects are likely to contribute to this result. On the one hand, the new products/services developed enlarge firms' product portfolio and can be sold to different customers, increasing the stream of revenues. On the other hand, having been selected by a prestigious customer, like a space agency, provides a signal about the quality of suppliers' products and their reliability. Consequently, firms improved their image and reputation, and acquired new clients, with a subsequent impact on sales and profits.

The coefficient of the variable *Governance structure* is positive, but never statistically significant, suggesting that the establishment of a tight purchaser-supplier relationship is not relevant to predict suppliers' economic performance. This is in line with previous studies (see, e.g., Florio et al. 2018) that found a significant impact of the governance type on business development only when intermediate outcomes were included in the regressions. Neither the dummy indicating whether the firm operates in a high-tech industry nor the TRL of the order delivered are associated with sales/profits with statistically significant coefficients. Similarly, the impact of firm-level characteristics like size, age, geographical location, years of activity in the space sector and share of revenues from space activities, is not statistically distinguishable from zero.

Focusing on column 2, the variables *Learning* and *Innovation* turn out to be the main determinants of suppliers' *Business development*. This suggests that the knowledge acquired during the collaboration and the development of new products/services encourage companies to undertake new types of activities and spin-off projects, and to enter new sectors. The coefficient of the variable *Governance structure* is positive and statistically significant as well, meaning that the establishment of a deep technical and scientific collaboration with the space agency helps suppliers enhance their business development. On the contrary, the impact of the other variables is never statistically distinguishable from zero.

Table 7 – Determinants of suppliers' economic performance (final outcomes)

	(1)	(2)	(3)
	Sales/Profits	*Business development*	*Employment*
Intermediate outcomes			
Learning	-0.167	0.744***	0.109
	(0.250)	(0.229)	(0.266)
Innovation	0.518**	0.443**	0.120
	(0.256)	(0.212)	(0.238)
Market penetration	1.515***	0.641	1.136***
	(0.343)	(0.448)	(0.434)
Governance structure	0.165	0.465**	0.078
	(0.254)	(0.228)	(0.213)
Additional variables			
High-tech	0.920	1.081	0.115
	(2.316)	(1.127)	(1.829)
TRL	-0.114	-0.109	-0.035
	(0.089)	(0.604)	(0.075)
Age	0.002	0.021	0.014
	(0.016)	(0.013)	(0.015)
Years in the space industry	-0.026	-0.021	-0.020
	(0.027)	(0.025)	(0.024)
Revenues from space sector	0.681	-0.847	2.291***
	(0.511)	(0.566)	(0.670)
Size dummies	yes	yes	yes
Geographical dummies	yes	yes	yes
Sector dummies	yes	yes	yes
N	110	110	110
Pseudo R^2	0.269	0.224	0.317

*** p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. Robust standard errors in parentheses**

Column 3 presents the coefficients of the model where the dependent variable is the *Employment* indicator. Among intermediate outcome, only the coefficient of *Market Penetration* is positive and statistically significant. This result suggests that the improvement of image and reputation and the acquisition of new clients is the main driver of new hiring. Among the control variables, only *Revenues from space sector* is significantly associated with increased employment, meaning that suppliers mostly active in the space industry are those that experienced a greater employment rise due to the collaboration with the space agency.

4.4 Robustness checks

▪ 4.4.1 Factor analysis.

To further verify our findings, we performed a robustness check by constructing the intermediate outcomes using an alternative approach. Rather than building these indicators as the arithmetic sum of different survey items, we performed a factor analysis (FA) on each of the three different groups of items previously used to build the *Learning*, *Innovation* and *Market penetration* indicators. Since the items included in each group, which describe the same dimension of intermediate outcome, are strongly correlated with each other, the FA provides just one single continuous variable for each group of intermediate outcomes (factor component), which can be used as alternative indicator. Table 8 provides the regression results obtained using these alternative set of indicators for the intermediate outcomes. As can be noticed, previous results are largely confirmed. The only difference is that in the regression where *Business development* is the dependent variable (column 2), the coefficient of the *Learning* indicator is now also statistically significant at the 10% level.

Table 8 – Robustness check using alternative indicators of intermediate outcomes

	(1)	(2)	(3)
	Sales/Profits	*Business development*	*Employment*
Intermediate outcomes			
Learning	-0.199	0.709*	0.151
	(0.479)	(0.408)	(0.505)
Innovation	0.987*	0.983**	0.182
	(0.528)	(0.406)	(0.508)
Market penetration	1.852***	0.981*	1.479**
	(0.424)	(0.501)	(0.579)
Governance structure	0.182	0.487**	0.096
	(0.255)	(0.241)	(0.222)
Additional Variables			
High-tech	1.002	1.411	0.273
	(2.368)	(1.008)	(1.808)
TRL	-0.102	-0.016	-0.024
	(0.087)	(0.087)	(0.074)
Age	0.002	0.018	0.013
	(0.016)	(0.013)	(0.015)
Years in the space industry	-0.022	-0.014	-0.017
	(0.027)	(0.024)	(0.024)
Revenues from space sector	0.647	-0.693	2.282***
	(0.508)	(0.546)	(0.672)
Size dummies	yes	yes	yes
Geographical dummies	yes	yes	yes
Sector dummies	yes	yes	yes
N	110	110	110
Pseudo R^2	0.258	0.196	0.312

*** p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. Robust standard errors in parentheses**

▪ 4.4.2 Controlling for objective balance-sheet data

To partially account for the subjectivity biased caused by the nature of data collection, we introduced in the regression models additional balance-sheet data, taken from the Orbis database. Specifically, we controlled for firms' sales, intangible assets (as a proxy for the R&D effort[9]), and solvency ratio (as a proxy for the capacity to meet long-term financial commitments).

Including "objective" controls necessarily causes a trade-off: on the one hand it attenuates the subjectivity bias; on the other hand, it further reduces the sample size in our regressions. That's why, even if we downloaded from Orbis a larger set of variables, we included only those with a sufficiently high number of observation available, considering their average over the years 2012-2018.

All these additional variables turned out to be not statistically significant in our regressions and did not affect our main results. The only exception is that the coefficient of the intermediate outcome "*Innovation*" becomes statistically insignificant. This is likely due to the high correlation between this indicator and firms' intangible assets.

Note that the inclusion of the three balance-sheet variables caused a reduction in the number of observations from 110 to 101. Estimated coefficients are reported in Table 9.

[9] The information on firms' R&D expenditure is mostly missing in Orbis, hence we used intangible as a proxy (see e.g., Castelnovo et al. 2018; Leoncini et al., 2017; Marin, 2014).

Table 9 – Robustness check including firms' balance sheet data

	(1)	(2)	(3)
	Sales/Profits	*Business development*	*Employment*
Intermediate outcomes			
Learning	0.003	0.892***	0.162
	(0.291)	(0.300)	(0.310)
Innovation	0.383	0.431*	0.030
	(0.275)	(0.237)	(0.243)
Market penetration	1.292***	0.671	0.880*
	(0.402)	(0.492)	(0.485)
Governance structure	0.030	0.453*	0.011
	(0.285)	(0.257)	(0.213)
Additional Survey Variables			
High-tech	0.410	0.627	-0.028
	(2.694)	(1.209)	(1.896)
TRL	-0.107	-0.053	-0.027
	(0.093)	(0.109)	(0.079)
Age	0.001	0.012	0.008
	(0.016)	(0.018)	(0.015)
Years in the space industry	-0.002	-0.010	-0.009
	(0.036)	(0.032)	(0.027)
Revenues from space sector	0.725	-1.016	2.301***
	(0.551)	(0.646)	(0.657)
Balance-sheet controls			
Avg Sales 2012-18	2.253	2.230	0.687
	(2.749)	(1.570)	(2.226)
Avg Employees 2012-18	-0.017	-0.012	-0.012
	(0.019)	(0.010)	(0.012)
Avg Solvency ratio 2012-18	-0.003	-0.004	-0.007
	(0.012)	(0.011)	(0.012)
Size dummies	yes	yes	yes
Geographical dummies	yes	yes	yes
Sector dummies	yes	yes	yes
N	101	101	101
Pseudo r2	0.273	0.225	0.315

*** p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. Robust standard errors in parentheses**

5. Discussion and conclusion

5.1 Evidence and insights

The study on the impact of space procurement on firms' performances showed the emergence of indirect effects that deserve attention for their relevance, both in firms' perspective and in the accountability of effective public procurement processes. We identified these effects as intermediate outcomes, and we isolated, observed, and measured these outcomes in the space sector.

Our research aimed to understand how intermediate outcomes appear in the procurement process and how they impact the performance of firms. The study benefited from the deep and articulated exploration of a specific industry (the space sector) in a given country, which resulted in an extensive understanding of the process, matched with rigorous quantitative analysis. The mix of methods and the triangulation of data rewarded us with rich insights for theory, policymakers, and practitioners.

We developed two hypotheses for the scope of our study. The analysis confirmed both. The test of the first hypothesis proves the occurrence of intermediate outcomes and their benefits to suppliers. The relationship with a space agency by the means of a procurement contract opens the way for acquiring new knowledge, improving technical know-how, and developing R&D and managerial capabilities (learning); while working on an ESA procurement contract for the Mercury Planetary Orbiter, a firm reported "to have started new research and development […], something a firm alone cannot afford, it needs a public procurer".

The procurement relationship also –as expected – boosts firms to develop new products, services, processes, and technologies (innovation); in this regard, a firm reported having "developed a smart digital platform for data gathering in the framework of the scientific programme GAIA now used in other programmes such as Exomars" under a procurement contract with ASI.

Lastly, firms acquire new clients and improve their reputation thanks to the relationship with the procuring space agency; this confirms the existence of an "indirect certificate effect" (Dai et al., 2020) that signals the procurement suppliers to new clients or investors. A firm reached new clients thanks to new product "sold to other firms in Italy and abroad" developed in the framework of a procurement agreement. This is in line with the changing policies for market creation found in NASA and ESA (Mazzucato and Robinson, 2018; Robinson and Mazzucato, 2019); our study went further and found this effect to be an indirect outcome from the procurement contract and not as a clear market-creating innovation policy goal at the basis of the procurement activity in the space sector.

The intermediate outcomes that emerge from the test of the first hypothesis have an impact on the economic performance of firms. In detail, the intermediate outcomes *innovation* and *market penetration* have impacts on the sales and profits of the firms; a respondent certified that the relationship with ASI "offered the opportunity to win contracts". *Learning* and again *innovation* are the main determinants of suppliers' business development, for instance, the creation of either a new business or R&D unit, spin-offs, and access to new markets, as in the case of a firm that started a "big data analysis business targeting space and non-space clients". Developing a new product is crucial to access new markets. *Market penetration*, in terms of the acquisition of new clients, allows firms to expand in size and hire new employees; for instance, a firm "opened a new branch in Germany, to provide logistics to astronauts".

5.2 Contribution

Our study makes two key contributions to existing research. It proves the existence of intermediate outcomes in the procurement relationship that were largely underestimated and widely ignored. We explored the dynamics of the procurement relationship in the space sector and found three intermediate outcomes in action during the procurement relationship, learning, innovation, and market penetration. These are indirect effects, which go beyond the formal requirements in the procurement contract and have been so far unexplored in terms of their theoretical, policy, and practical implications. As a second contribution, we developed a model that evaluate the relevance of each intermediate outcomes on the suppliers' economic and social performance.

Our study contributes to our understanding of how suppliers benefit from the procurement relationship beyond the pure purchaser-supplier agreement and gain positive effects that translate into additional learning, innovation, and market penetration. Scholars have largely studied public procurement for innovation; with this study, we look at the outcomes of procurement from the suppliers' perspective more than that of the purchasers, and we looked at the diffusion of outcomes other than the innovation target of the procurement contract. We found underappreciated outcomes that were beneficial to firms and their performance that went beyond the end of the public procurement contract. While most studies fall short in identifying the

intermediate and final outcomes of innovation in public procurement (Uyarra and Flanagan, 2010; Obwegeser and Müller, 2018), our study presents a novel approach to account for the innovative results of public procurement.

The importance of public procurement in innovation policies is known, documented, and relevant in the academic debate. Scholars insist with policymakers to avoid risk-averse behaviour and promote a "cultural and organizational change in public administration" (Petrella, 2013 p. 10) for the successful implementation of innovation policies based on a public-procurement strategy (Caravella and Crespi, 2020). Others, notably Robinson and Mazzucato (2019), look precisely at the space sector and urge the European Space Agency to act to facilitate market creation. Others suggested the importance of state-led collaboration in the emerging space industry, e.g. in Korea (Lee et al., 2021).

The insights from our study suggest policymakers should take into account the chain reaction started by space agency procurement that results in intermediate and final outcome for the firms, like in other basic research procurement that impacts on suppliers (Dal Molin and Previtali, 2019)

In terms of the accountability of public procurement, as well as the consideration of related risks, policymakers should take into account the role of the public sector in shaping innovation in unknown directions (Uyarra et al., 2020), and its importance for the creation of new markets (Bleda and Chicot, 2020). This should allow for a greater discretion in the use of funding.

The implication of the present study calls on procurement practitioners from both sides – purchasers and suppliers – to account for intermediate outcomes and build relationships that can further boost firms' performance.

From the purchaser's perspective, the public procurer should be aware of the whole range of the procurement impact. While purchasers currently have incentives to undertake low-risk projects, including for budget reasons, in the future they should also count for the positive effects on firms that can return in the form of better innovation management and technological capabilities, greater market sales and employment. Long-term government policy is therefore important to assure the success of public procurement, both technically and commercially (Aschhoff and Sofka, 2009)

From the perspective of the supplier, as others have already suggested (Obwegeser and Müller, 2018), firms should look at building professional ties with governments with the aim of having a positive effect on their performance.

5.3 Limitations and future studies

Our study looks specifically at one industry in one country, the space sector in Italy, therefore, there are limitations regarding the generalizability of our findings, especially to other industries due to the prominent role of the public purchaser in the space sector. In other industries, for example, a long-term perspective might be less viable, in others the role of the public sector in opening and shaping new markets could be negligible. We acknowledge that there are significant historical factors that can interfere with the object of our study due to its complexity, such as public budget constraints and more market-oriented logics. To mitigate these limitations, we invite future research to further test our hypotheses and contribute to their theoretical development. Supporting evidence already exists in the field of high-energy physics (see Florio et al., 2018, for an analysis of the procurement benefits on CERN suppliers).

Once a solid theory on the role of intermediate outcomes has evolved, future research could better measure empirically their impact and try to include them in a workable framework for the analysis of costs and benefits in public procurement that could include indirect and long-term effects. While potentially affected by selection bias (for instance we only investigate suppliers without a control group), our study points to positive effects related to procurement and documents that its outcomes spread across firms, e.g. subcontractors. This cascade effect is equally underestimated and hard to detect. Our study calls for more research investigating the emergence of intermediate and final outcomes in second and third tiers suppliers.

A related and relevant issue concerns the interdependencies of intermediate and final outcomes and the direction of their relations. For example, in our context, it is possible that the increase in profits experienced by suppliers may be partly invested in new R&D activities, which in turn strengthen firms' innovation, generating a feedback effect, consistent with the complex nature of the cumulative process of learning and innovation (in this regards, see some classical works from the evolutionary economic literature, e.g. Dosi et al., 1988; Teece et al, 1994). The present paper has not investigated the existence of loops and feedback effects, but we believe this is an important matter that future research should address, also considering the timing of the PPI effects.

Indeed, another issue worth investigating is the timing of the intermediate and final outcomes. It is not clear when firms achieve outcomes during the procurement relationship, at what stage of the interaction, and how long the outcomes affect firms and their economic performance during the relation with the procurer and after the end of the contract. So far, few studies have focused on how much time is needed for collaborations between firms and RIs to generate positive externalities to suppliers. However,

extant literature suggests that, in this setting, the absorption process of new knowledge may be quite long. Specifically, Bastianin et al. (2021) showed that the procurement relationship with a large research infrastructure (i.e., the CERN) has a positive impact on suppliers' patenting activity but such effect requires a relatively long gestation lag in the range of five to eight years.

A methodological limitation worth acknowledging is that our analysis is based on data collected through an online survey. Every survey to company managers provides some new and fresh statistical evidence but is likely to be affected by self-selection as well as respondents' judgment and memory (see e.g., Bertrand and Mullainathan, 2001; Tempelar et al., 2020)[10]. Specifically, there might be sample selection issues since only companies that experienced a very positive (or very negative) relationship with the ASI may decide to answer the online survey. In addition, some companies might have gone bankruptcy over time, hence are not included in the sample.

Moreover, as far as the econometric analysis is concerned, we recognize that the small size of our sample (110 observations) may affect the robustness of estimation results (see Cohen, 1988). However, Bergtold et al. (2018) studied the impact of sample size on estimate's robustness in logistic regression models running several simulations on alternative datasets. They showed that, even if small sample size can negatively affect the quality of parameter estimate, marginal effects estimates are relatively more robust to sample size.

Despite the abovementioned limitations, our study has explored a novel concept and contributes to a growing stream of literature that calls for a deeper understanding of the impacts of public procurement beyond what is predictable and controlled (Uyarra et al., 2020) and a limited view on what is perceived as innovation in public procurement (Obwegeser and Müller, 2018). We did so by applying a mix of methods that included hypothesis-generating in-depth interviews, analysis of primary survey data, and econometrics. The triangulation of sources and techniques support the soundness of our theoretical contribution. We believe there is a promising area of research in the established field of public procurement with great opportunities for theory development and innovation policy.

[10] Nonetheless, note also that Nicoletti and Prior (2006) showed that subjective and objective economic indicators, collected with very different methodologies (e.g., official statistics vs surveys) may be significantly correlated with each other.

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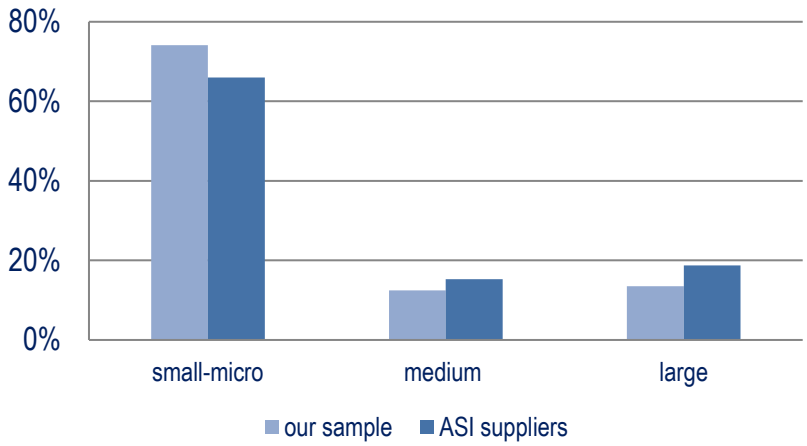
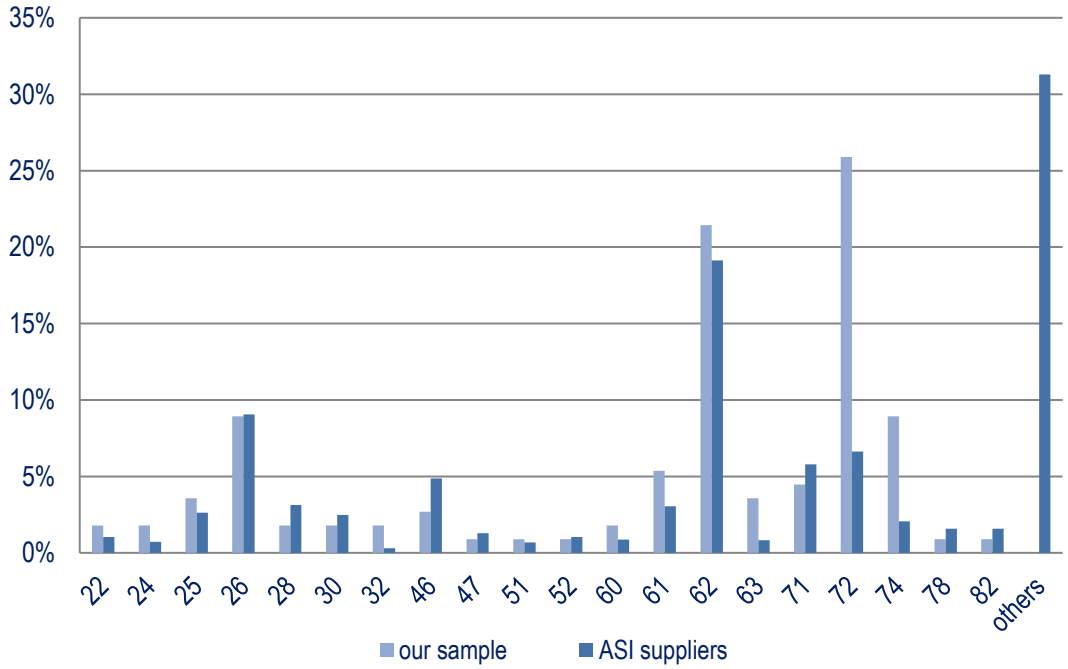
Appendix

Figure A.1 – Size: sample of respondent firms vs target population.



Note: we adopted the OECD size classification, based on the number of employees. The firm is "smal-microl" if N. of employees<50; "medium" if 50 ≤ N. of employees < 250; "large" if N. of employees ≥ 250.

Figure A.2 - Activity sector: sample of respondent firms vs target population.



Note: The item "others" includes NACE codes that appear in the target population but are not represented in our sample; among them, none exceeds 5% of the target population. The three most relevant are codes 43 (4.67%), 70 (2.29%), and 33 (1.43%).