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THE SOCIO-ECONOMIC IMPACT OF PUBLIC POLICIES IN THE SPACE SECTOR IN ITALY[1]

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0. Preamble

[1] The Italian Space Agency (ASI) commissioned to Department of Economy, Management and Quantitaties Methods University of Milan a cost-benefit analysis of public policies in the space sector. The study was coordinated by Professor Massimo Florio, Department of Economics, Management and Quantitative Methods. The head of project for the ASI was Doctor Simonetta Di Ciaccio, Innovation and New Space Economy Unit. The project's research group was composed by: Professor Massimo Florio, Doctor Stefano Clò, PhD; Doctor Paolo Castelnovo, PhD; Doctor Gelsomina Catalano; Professor Chiara Del Bo; Professor Carlo Fiorio; Doctor Francesco Giffoni, PhD; Professor Anna Giunta; Doctor Matteo Landoni, PhD; Doctor Veronica Lupi, PhD; Professor Davide Maino; Professor Giancarlo Manzi; Doctor Valentina Morretta, PhD; Professor Matteo Turri; Doctor Davide Vurchio, PhD, Professor Lorenzo Zirulia.

The topic of the socio-economic impact of public policies for space, which in Italy regard both the Italian Space Agency, directly, and the national contribution share in favor of the Italian Space Agency, indirectly, is key to be able to define an assessment metrics of the funding choices that have been made and the validity of the investments, in order to highlight the strengths on which to bet but also the weaknesses to improve on, with specific correction actions.

The Italian Space Agency's activity is aimed at improving the design skills and expertise of the national industrial network, strengthening the level of scientific and technological research and, especially, raising the competitiveness of the industry in general, by enhancing its social impact, also in terms of quality employment. For these purposes, therefore, we need an ongoing analysis activity serving as control and feedback. Such need is further strengthened by the dynamic moment which the space sector is experiencing in the field of what is commonly known as *space economy*, which also requires more innovative approaches for *public procurement*.

1. Introduction

The purpose of this work is assessing the impact of the Italian Space Agency (ASI)'s activity, directly and through its participation in the European Space Agency (ESA), on the innovation and *performance* by several stakeholders of the Italian space system:[2]

I. **Companies which provide upstream technologies** and participate in the value chain, including research, development and manufacturing of enabling space infrastructures, including technology subcontractors.
II. **Companies and other downstream organizations in the field of Earth observation (EO)**: private and public stakeholders who **are intermediate users** of EO data and provide services and applications to end users (public administration, companies and citizens) in several areas.
III. **The scientific community active in space research**: research centres (private or public, universities or other institutes), which have worked in various capacities with the ASI to carry out a project and produced knowledge.

[2] A recent report by Intesa Sanpaolo Research Department on the Italian *space economy* has identified 286 companies which are currently active in this sector (Intesa Sanpaolo, 2021). Our study has identified, in the upstream industry, a potential number of 778 companies which, in a long period of time (1987-2018), have worked with the ASI and/or the ESA, even if in a limited manner in several cases. We have identified budget figures on 461 companies. In the downstream sector of Earth observation (which doesn't include, therefore, those companies which operate in other downstream sectors) we have identified 89 companies which include, again, operators with a limited role in the industry.

From a methodological perspective, the research was based on a dual mode, aimed at monitoring the convergence of the results, as well as on a comparative analysis of the international researches on the socio-economic impact of public investments in space:

- **Direct survey** on three types of stakeholders, with the participation in the project of **305 key witnesses**;
- **Econometric analysis** of historical series (1990-2020) of budget figures, patent data, scientometric data, with **over 20000 observations.**

2. Theoretical and empirical background

2.1 The upstream sector

The analyses related to the upstream sector which are presented in this work draw inspiration from three strands of economic literature which are regarded to be relevant:

- The literature on the impact of public *procurement* for innovation (PPI) on the performance of the suppliers;
- The literature on the technological transfer which takes place between the space sector and the other economic sectors;
- The literature on the *link* between university and industry which, in our case, is projected on the *link* between university and space sector.

Several works have dealt with public *procurement*, that is the process through which public authorities purchase goods or services or commission a work. Such process can serve as a stimulus for domestic demand and, in specific circumstances, can trigger technological innovation.[3] There are several existing types of public *procurement* but, for the purposes of this study, our focus will be on *public procurement for innovation* (PPI), which takes place when a public authority places an order for products or services which aren't available yet on the market or aren't broadly available, and the order can be processed within a reasonable amount of time. With this type of *procurement*, public authorities – through companies, public companies or institutions or large research centres – act as *launch customers* and promote research and development by suppliers, support innovation and, ultimately, improve productivity and inclusivity (OECD, 2017).

Even when a public organization doesn't participate directly in the innovation process conducted by companies, it can encourage the technological process and support the

[3] See Aschoff e Sofka (2009); Salter e Martin (2001).

development of new technologies, by strengthening the innovative potential of companies through the demand of new products to the technological frontier. [4] However, in a few cases the public contracting authority is actively involved in the manufacturing of such products: an example of this is CERN, which makes its infrastructures and *know-how* available to suppliers so that they can conduct experiments, or often contributes to the design and development of the requested products.

Generally, the space programs of public agencies, and particularly European agencies such as the ASI or the ESA, mainly define the infrastructure scientific/performance/cost requirements in their *procurement* activity, and leave the responsibility for the technological project, detailed specifications, overall design and manufacturing to companies. However, they ask companies to apply specific standards and processes (ECSS standard https://ecss.nl/) with intermediate steps (program review) which assess the consistent development of the activities. The belief that PPI is capable of improving companies' economic performance and their innovative potential is supported by a broad economic literature,[5] also thanks to the fact that, usually, the contracting authority bears the risks related to investments in research & development and innovation. Such risks can deter private companies from bearing innovation costs, which leads to a suboptimal level of innovation (Mazzucato, 2016).

The majority of the empirical studies which have focused on PPI consists of case studies and *surveys* to suppliers of contracting authorities, whereas just a few works have applied econometric techniques to companies' budget figures.

The first, and for now only, research which has applied econometric techniques to companies' budget figures, obtained from *online* databases with international coverage, is by Castelnovo et al. (2018), and has studied CERN's network of suppliers. The results of the analysis have shown that becoming a supplier of CERN has a positive impact on the investments in research & development, on the likelihood to patent new products, on the productivity and economic *performance*. These results are valid, in particular, for suppliers who operate in *high-tech* sectors, whereas the impact on low-tech companies is lower and often not statistically significant.

As regards the space sector, a group of researchers from the University of Bergamo, in a study commissioned by the ASI (Graziola, 2009) has conducted an econometric analysis to

[4] See Edquist and Zabala-Iturriagagoitia (2012), Ghisetti (2017).
[5] See Martin and Tang (2007), Edquist and Zabala- Iturriagagoitia (2012), Autio (2014), and Vuola and Hameri (2006).

assess the existence of a *spillover* from the space sector and, more in general, from *high-tech* sectors, towards the added value and productivity of the manufacturing industry in Europe. Their results show that the innovative activities (measured by the expense in research and development or the number of registered patents) performed in *high-tech* sectors improve the performance of the rest of the manufacturing industry, suggesting the existence of relevant technological *spillovers*.

The benefits coming from the partnership with research institutions/infrastructures and public agencies are not limited to the positive effects which may derive from the *procurement* relationship. Economic benefits for companies and, more in general, for specific sectors – or for the whole economy – can arise from the transfer of technologies which were originally developed for specific goals or projects which, later on, have found application in different fields.

Recognized since the '60s of the XX century – years when the *National Aeronautics and Space Administratio*n (NASA) started to promote transfer programs, supporting the demand for technological information – the benefits for other sectors, coming from the transfer of technologies invented for space, have led to the development of innovations in different sectors, including the automotive sector, civil defense, mobile applications, navigation, telecommunications, safety or healthcare.

There are several definitions of the concept of technological transfer. For example, Bozeman (2000) defines it as the process which allows the transfer of a technology from an organization to another organization, whereas the ESA interprets it as the adaptation process to another sector (non-space sector) of technologies which had originally been developed for a sector (space sector) (ESA, 2012).

The number of studies which aim at investigating the process of technological transfer and the economic benefits deriving from it is constantly growing.[6] As in the case of the literature on PPI, empiric evidences are mainly based on case studies and *surveys*, whereas econometric studies represent a minority.

Unlike the case of technological transfer or innovation coming from public *procurement*, the effect of the partnership between contracting authority and research institution (public research body or university department) is less easy to identify. Today, academic research plays a key role in the industrial innovation process (Cohen et al., 2002; Mansfield, 1991).

[6] To learn more about the literature – both theoretical and empirical – on technological transfer, please refer to Venturini and Verbano (2014).

Such role, however, is not easy to quantify, because it expresses itself through a *knowledge spillover*: the results obtained during a partnership generate a flow of knowledge which is crucial for the birth of new projects, publications or patents (ESA, 2012).

The process of knowledge transfer from and to the university happens through different channels, including personnel mobility, informal contacts, consulting relationships and the development of joint research projects (D'Este and Patel, 2007). There are several metrics used in the literature to empirically assess the outcomes downstream of the collaborative process between university and industry (Perkmann et al., 2013), including the number of demands for patents, accepted patents, publications in *peer-reviewed* journals, number of doctoral and postdoctoral positions promoted during the partnership, number of joint supervision agreements, number of new *spin-off* projects, number of interns. However, according to D'Este and Patel (2007), *spin-off* patents and activities play a relatively limited role in the relationship between university and industry, since such relationships are rarely motivated by the perspective of marketing a product.

Resorting to partnerships between the world of academic research and industry is justified by the presence of several benefits, which have effectively been categorized by Ankrah and Al-Tabbaa (2015) as economic, institutional and social. The economic benefits are those coming from the availability of new products or processes for industry, marketing and business opportunities for universities, the contribution to the development of local economy and the income from patents or intellectual property rights for both parties. The institutional benefits are linked to the possibility of working on joint publications, internship and employment opportunities for students, the availability of a test bench to obtain *feedback* on research ideas, the access to cutting-edge technology and a wide expert network, the possibility to recruit talents and improving the innovative potential of the industry. Finally, social benefits are linked to the possibility of providing a service to the community, particularly in the case of universities, and improving reputation.

2.1 The downstream sector of Earth observation

In the last decade, more and more high-resolution satellite images have become accessible to public administrations, *policymakers*, researchers and scientists, increasing the quantity and quality of available data and information on our planet's physical, chemical, biological and infrastructure characteristics. In fact, Earth observation is capable of providing valuable information to both the public and the private sector, which allows to face – simultaneously and with new tools – global challenges such as climate change and air

pollution and promoting local applications including, for example, the implementation of precision farming techniques and the monitoring of urban and transport infrastructures.

Earth observation can be compared to a social infrastructure which provides a unique perspective on the world and supports both the progress of civilization – contributing to more awareness on environmental, social and economic topics – and the concrete actions aimed at a sustainable and effective management of global and local resources (Onoda e Young, 2017).

Satellite data is increasingly used in scientific research to investigate and assess a wide range of topics. It's a useful tool to investigate phenomena such as ice coverage (Von Schuckmann et al., 2016), landslide (Kalia et al., 2017), differences in the types of crops (Inglada et al., 2015), post-eruption volcanic ashes (Schmidt et al., 2015), chlorophyll concentration and temperature of ocean surface (Von Shuckmann et al., 2016).

The use of Earth observation data is particularly useful when the lack of data limits the possibility to assess specific phenomena. That is the case, for example, of data related to *nightlights* provided by the NOAA; Henderson et al. (2012) use such data to promote the growth of the Gross Domestic Product (GDP) in remote areas of the world, where such information is of poor quality. Lee (2018) analyses regional inequalities, looking at the distribution of economic activities in North Korea since no official information is available, while Storeygard (2016) approximates the GDP of the main cities of Sub-Saharan Africa, to assess the correlation between the distance from the main ports and the economic *performance*. Clark et al. (2017) show that the rate of economic growth of the Chinese regions is higher than the rate reported by the official statistics, while Costinot et al. (2012) show how climate change is negatively influencing the global GDP (- 0.26%). Furthermore, the data on night light has allowed Hodler and Raschky (2014) to provide evidence of how, for a global *panel*, the regions of origin of the current political *leaders* enjoy more night light than the other regions.

EO data is further used to build new data sets on specific topics related to information which can't be obtained through official statistics, as in the case of Marx et al. (2017), where satellite data is used to approximate the quality of the shacks inhabited by the residents of Kenyan slums. By crossing such information with the information available from *surveys*, the study shows how residents pay lower rents and live in higher quality houses if their ethnic group matches that of the owner.

3.1 Upstream impact in all sectors

The first *step* in completing the project was mapping the companies involved in the public procurement of the Italian space sector between 1987 and 2018 and collecting company information, economic-financial information and information on the innovative potential of such companies in the pre- and post-*procurement* periods. Such activity allowed to create a database of **778** Italian **companies** which were involved for a long period of time, directly or indirectly, to a larger or lower extent, in the provision of goods and services for the ASI and other space agencies. Such database has been used to identify the companies to be involved in the data collection *via an online survey* and direct interviews and for the subsequent econometric analysis, aimed at quantifying the impact of *procurement* for the space sector on the economic/financial and innovative results of its suppliers.

The **online survey**, conducted throughout 2020, involved **112 suppliers of the ASI and the ESA** – a sample which accounts for **86**% of the **overall volume** of ASI procurement **contracts** from 1987 to 2018, of which 36% are located in Northern Italy, 47% are located in Central Italy and 17% are located in Southern Italy and the Islands. **Three quarters of the suppliers are SMEs** (less than 50 employees).

If the *procurement* activity of the client agencies in the space sector has an impact on suppliers, such impact should manifest itself, first of all, on the technological content of the offered products/services and, therefore, on the innovative activity of companies.

As regards **process innovation**, almost all the surveyed companies (90%, N = 101) have recorded an improvement of their technical know-how and, therefore, a better quality of the offered products and services (76%, N. = 85). A further effect that has been reported regards the research and development activity: 71% (N. = 80) of the surveyed companies have observed a significant improvement of the research and development activity, including the launch of new dedicated teams or units. In over half of cases, the supply partnership led to an improvement in terms of business management and organization (62%, N. = 69) and, subsequently, of production processes (54%, N. = 60).

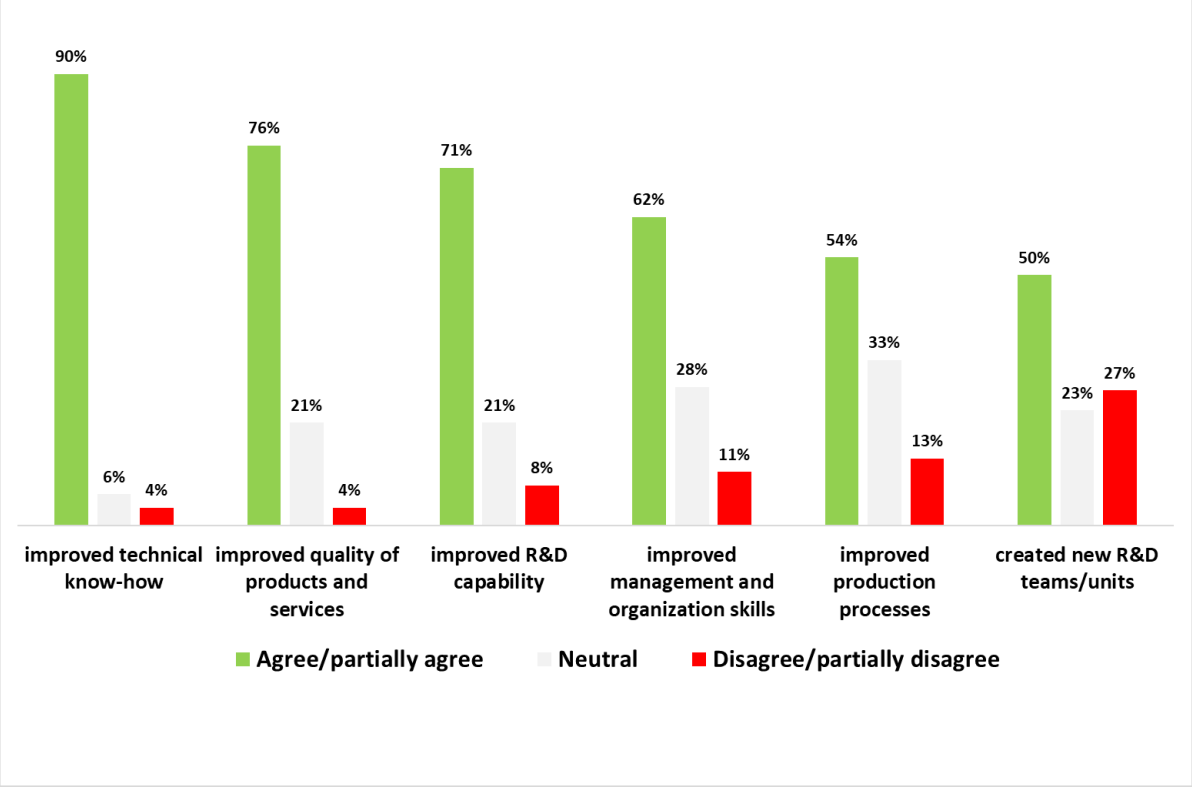
Process innovation has been accompanied by **product innovation**. In line with the acquisition of technical *know-how*, the most widespread effect regarded the development of new technologies (63%, N. = 71), followed by the introduction of new products (55%, N = 62) and services (48%, N. = 54). The reported impact on the registration of trademarks and patents and the start of *spin-off* projects has been smaller: about 20% of the surveyed companies (N. = 25) have reported this type of effects.

Generally, higher innovation corresponds with a subsequent improvement of the **economic *performance* of a company**. Consistently, we observe a widespread

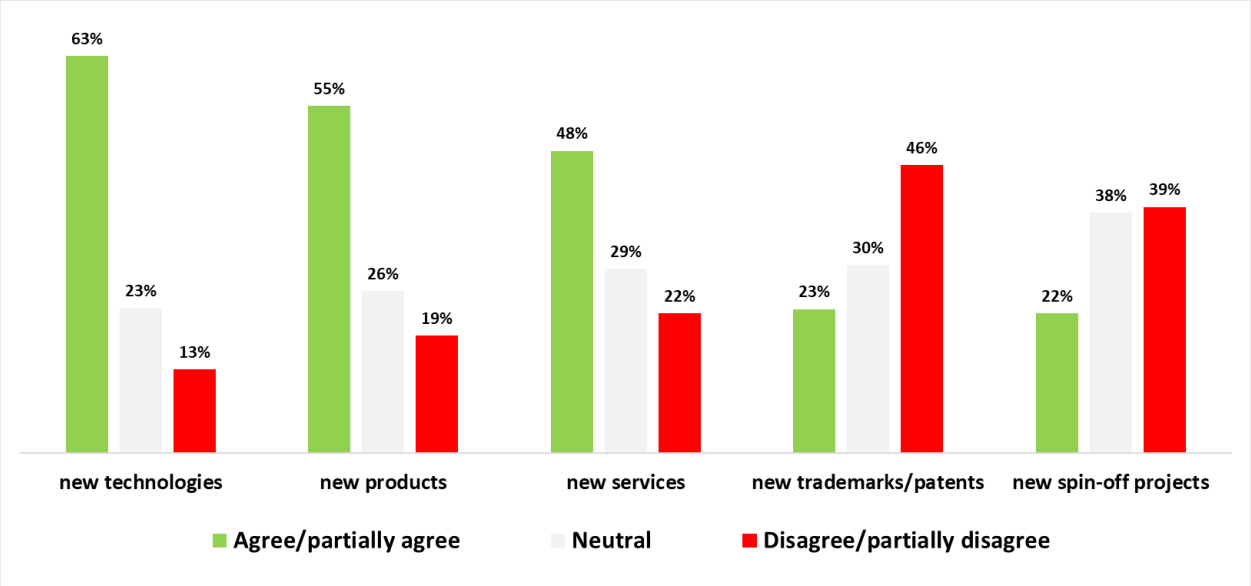
improvement of the turnover (75% of companies, N. = 84), also thanks to the widening of the number of customers (59%, N. = 66) and the break into new markets following the cooperation with the commissioning agency (45%, N. = 50). In particular, during the survey the suppliers were asked to identify the new customers acquired through the supply relationship. In most cases (60% of the surveyed companies) these are new orders from companies working in the supply chain of the space sector, both in Italy and abroad, while 50% of the surveyed companies have mentioned they have come into contact with institutions and research centres. Furthermore, 38% (N. = 43) of companies have recorded an increase in profits that can be attributable to an increase in turnover rather than a reduction of production costs.

Process innovations

Thanks to the supply contracts with the commissioning agency, your company has…

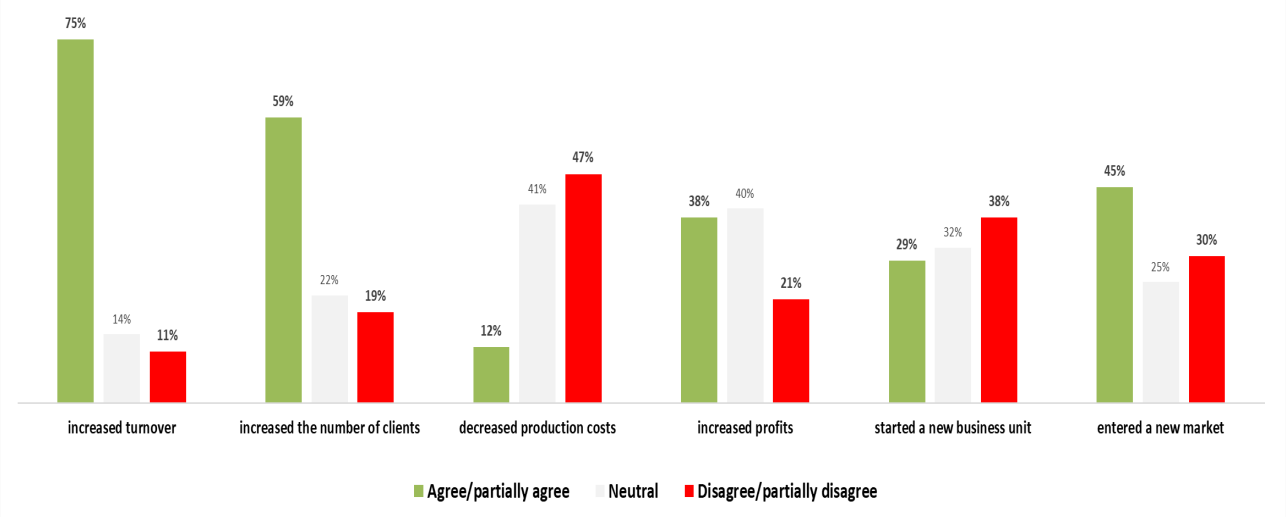


Following the supply contracts with the commissioning agency, your company has developed….



Indirect final effects on the economic performance of the company

Following the supply contracts with the commissioning agency, your company has …



As regards the **impact of the supply relationship on the number of employees** of the suppliers, following the supply relationship with the commissioning agency, 41% (N. = 46) of the surveyed companies have reported an increase in the number of employees: 26

companies have hired permanent staff, while 20 companies have hired temporary staff. As expected, and although positive, the impacts on the employment dynamic are more limited than those on innovation and the other economic performance indicators, such as turnover and acquisition of new clients. However, the data on the increase in the number of employees highlights, subject to our sample, a positive impact of the space sector also in terms of employment, as well as in terms of higher competitiveness of companies, thanks to their better economic performance following the supply relationship.

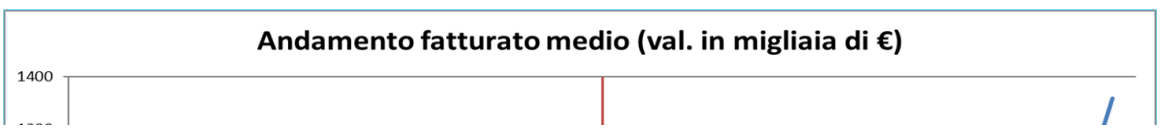
The analysis of the **impact of the supply relationships with the ASI along the value chain** has been conducted through questions aimed at investigating any direct (for example on innovation) and indirect effects (on the economic performance) on subcontractors. Out of the 112 companies which participated in the survey, 62 companies (55%) have made use of subcontractors to complete the project(s) on behalf of the commissioning agency. The positive *spillover* effects generated by the supply activity propagate along the value chain related to the space sector, at least until the second level of service. According to the perception of the responding companies, there is a transfer of technical knowledge and *know-how*, including to the subcontractors themselves (45 companies out 62, that is 73%, confirm this hypothesis), and the latter also experience process and/or product innovations and improvements in production processes.

The **interviews** with company representatives (the so-called *"face-to-face"* interviews) have allowed our research *team* to complete and deepen the information collected through the online *survey*. In particular, 12 pilot case studies on ASI suppliers (space systems, services, manufacturing, small satellites, engineering and carrier rockets) have highlighted an enrichment effect of technological development and product innovation strategies and, subsequently, strategies to open up new markets.

The **econometric analysis** on a highly representative sample of 461 Italian space sector suppliers (budget figures and patents) confirms **objectively** how suppliers have improved their economic performance and innovative potential by: **a statistically significant, long term increase in turnover and a 2-3 times increase in the number of registered patents** (even if, in the survey, companies do not identify the main impact channel with this innovative output). This can be observed both in an analysis before and after receiving the order, and in comparison with a control group of foreign companies which do not work as ASI suppliers (but operate in the same sectors).

Average turnover (EUR thousands)

Revenues performance of ASI/ESA suppliers, before and after receiving the order



Time k=0, year when the company received the order from the ASI

For what concerns the **aggregate economic impact of the direct effect alone**, the annual value of orders from the ASI and ESA obtained by Italian companies is estimated at approximately 650 million euros (average 2018-2021). Assuming a direct multiplier for companies which is equal to 3 and an added value-turnover ratio which is equal to 47% (average of the period 2016-2018), the annual impact on the GDP is over 916.5 million euros. The employment impact of investments is estimated at about 7000 new units per year. The annual economic benefit is 193, 5 million euros (EBITDA margin of 9.9%). The *Payback period*, that is the payback period of the public investment, is fast: 3 years and 4 months. Using a 3% social discount rate, as per EC guidelines on the cost-benefit analysis of investment projects, the benefit-cost ratio (5-year horizon) is positive and equal to 1.36.[7]

3.2 Downstream impact in the Earth observation sector

The study on the downstream Earth observation (EO) sector in Italy has been conducted through two direct surveys, targeted at public and private companies and research centres as **intermediate users** of EO data. Therefore, such companies and research centres have

[7] The choice of a direct multiplier value of 3 is prudential. It's an average value, estimated in the literature on the ESA, by excluding indirect and induced effects. In the light of the calculations we made based on: i) value of the average turnover of ASI suppliers in the period of analysis (2004-2018); ii) average amount of orders received during the same timeframe; iii) ratio of the average annual impact of ASI procurement on the turnover of suppliers (estimated through a multivariate linear regression); the multiplier, calculated over a 6-year time horizon (that is the average duration of the post-procurement period observable in our data) is equal to 6.3 (ranging from 2.3 to 10.4).
Since the distribution of both the orders and the turnover of companies is highly asymmetrical (there are few large companies which have received very large orders), it might make sense to consider the median, rather than average, value of turnover and orders. If we consider such values, the multiplier, which is calculated again over a 6-year time horizon, is equal to 3.2 (ranging from 1.2 to 5.3).

the *know-how* and technical skills to process EO data, for the purpose of providing services and applications to end users.

The sample of companies includes **63 Italian companies operating in the** downstream **EO sector**. In line with what has been stated by the surveyed industry experts, the entire population of companies operating in the Italian downstream sector consists of nearly 90 companies. Therefore, our sample is a good approximation of downstream companies, with a response rate of over 70%. 46% of the sample are made up of micro enterprises with less than 10 employees. 32% of the sample are made up of small enterprises with less than 50 employees, 10% of the sample are made up of companies with less than 250 employees and 13% of the sample are made up of large enterprises. The sample composition highlights the critical role of large and medium-sized enterprises in the *Information Technology (IT)* sector, which penetrate the market by directly opening new EO units and divisions. The average number of employees involved in EO activities is 21. At geographical level, 49% of the companies are located in Central Italy, another 43% are divided into regions of Northern and Southern Italy, the remaining 8% are located in several regions.

The sample of research centres is made up of 57 respondents (researchers) belonging to several public and private centres. In particular, in 33% of cases they are researchers who belong to Italian university departments, in 19% of cases they are researchers from the National Research Council, whereas the remaining 48% of researchers work in public administrations and private research centres. The sample shows how, on average, such operators have been working in the EO sector for about 25 years. The average number of researchers who work in the EO sector in the surveyed research centres is 10. 49% of research centres say that their percentage of EO turnover ranges from 1% to 25%, whereas 16% of research centres say it ranges from 26% to 50%. At geographical level, the sample's research centres are distributed in a similar manner as companies. In fact, 32% of research centres are located in regions of Northern Italy, 49% of them are located in Central Italy and 19% of them are located in Southern Italy and the Islands.

The companies' EO services and applications are targeted at the following customers and end users: Italian public centres (37% of cases), large Italian companies (27%), foreign companies (27%), regions (19%), provinces, municipalities and the national government (16%). 69% of research centres work on commission for Italian public centres (national government, regions, provinces and municipalities).

The products and services offered by companies and research centres are hardware and software (63% of companies, 28% of research centres), processing of EO data and

innovative EO applications (63% of companies, 82% of research centres), consulting services (40% of companies, 26% of centres), Geo Information System services (40% of companies, 51% of research centres).

The ESA Copernicus Sentinels are the satellites which mostly support the EO activities of companies and research centres and are used, respectively, by 75% and 79% of the respondents, along with COSMO-SkyMed, Landsat, Prisma and Modis.

As regards the socio-economic benefits for the intermediate users of the downstream sector, the results of the survey highlight the key contribution of EO to the improvement of operational processes.

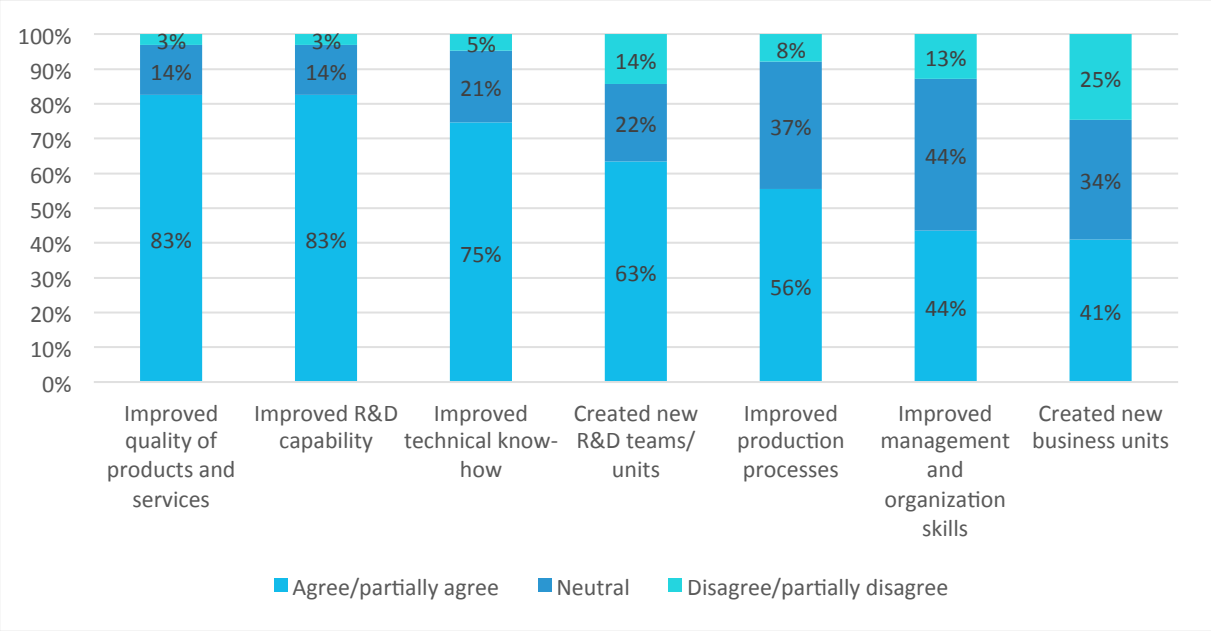
As regards **companies**, according to the majority of them (83%) the availability of EO data has contributed to improve the quality of products and services. It's the same percentage as those who say they have improved their research & development capabilities thanks to satellite data, whereas 63% of companies say they have created new research & development teams/units. 75% of companies have improved their technical *know-how*, which means that, thanks to satellite data, they have improved their technical knowledge and skills required to perform certain activities within their industry, even outside the EO sector. 56% of companies have improved their production processes, whereas 44% of them have improved their management and organizational skills. 41% of companies have opened new business units.

Furthermore, the use of EO data has allowed to improve the economic performance of intermediate users and the innovation of products and services. 86% of companies say they have developed new services, whereas 79% of them say they have developed new products. 63% of companies have developed new *software*, 59% of them have developed new technologies, whereas 55% of companies have contributed to the production of scientific publications. 50% of the surveyed companies have entered new markets or sectors, whereas 33% of intermediate users have registered new *spin-off* projects. Only 31% of companies have developed new brands and patents.

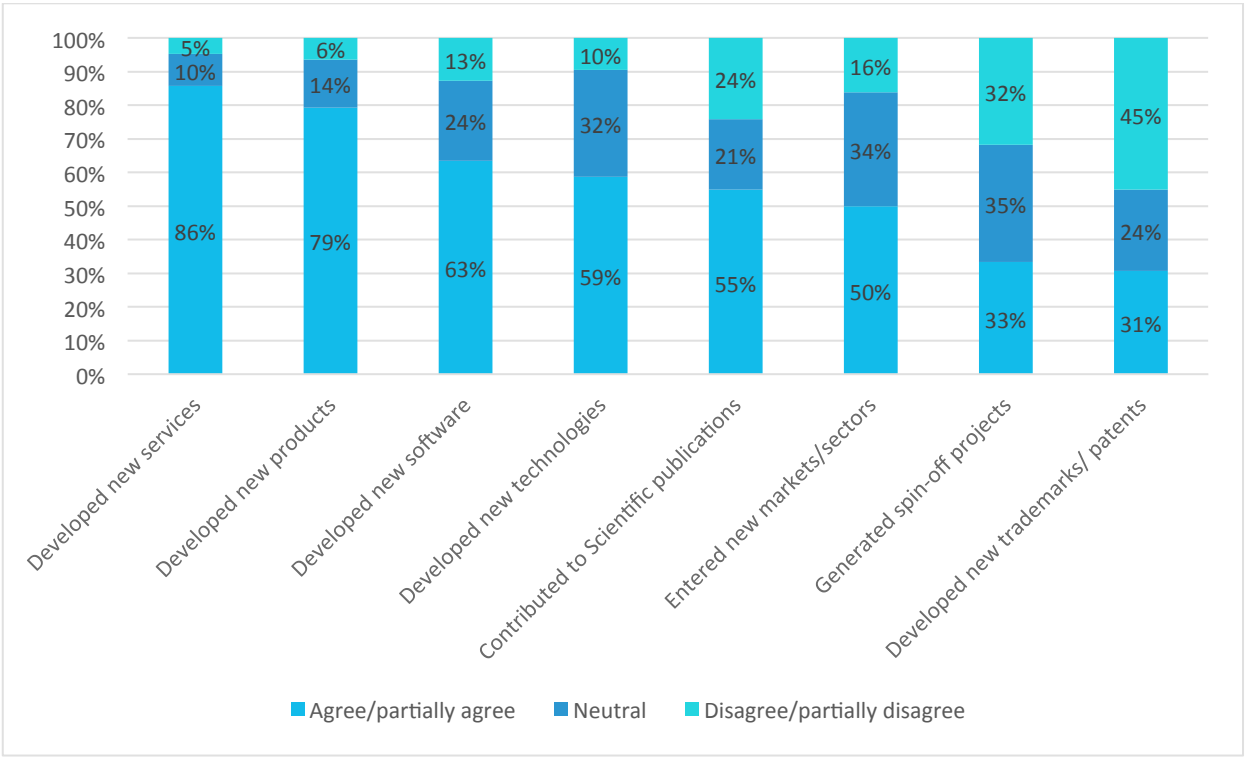
As regards the final impact of the economic use of EO data, 65% of companies say they have increased their medium-long term turnover, 60% of companies say they have increased the number of customers, 45% of companies say they have increased their profits, whereas 13% of them have reduced their production costs. Furthermore, in terms of effect on the employment, 30% of companies say that, thanks to the EO data, they have increased their number of temporary employees, 52% of companies say that they have

increased their number of permanent employees, whereas 38% of the surveyed companies have increased their number of partnerships with self-employed workers.

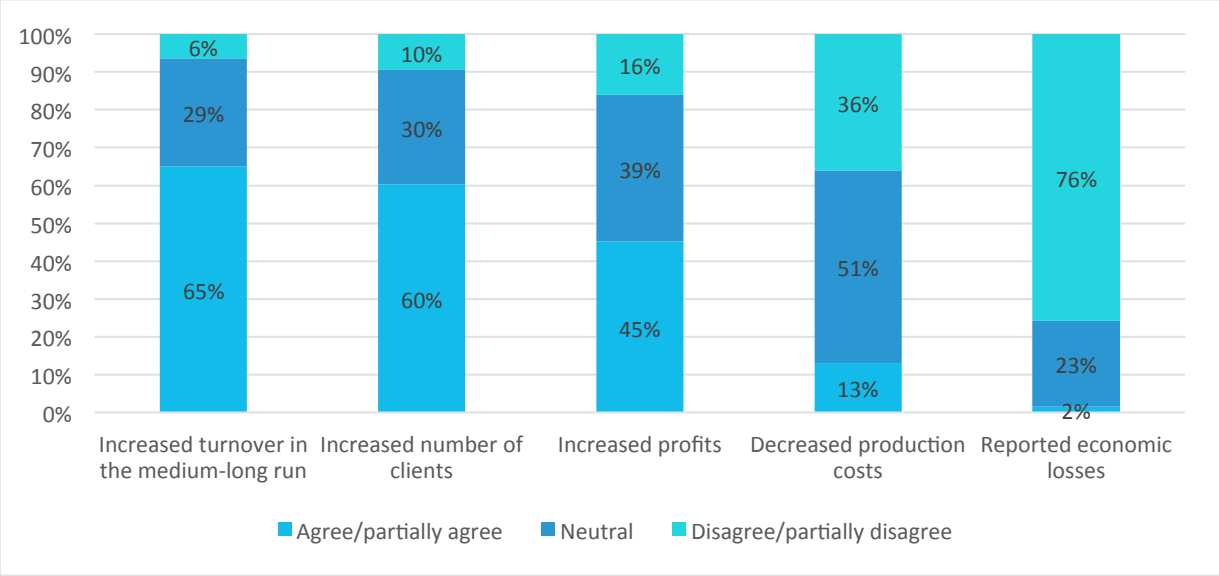
EO contribution to companies' process innovation



EO contribution to companies' output and process innovation

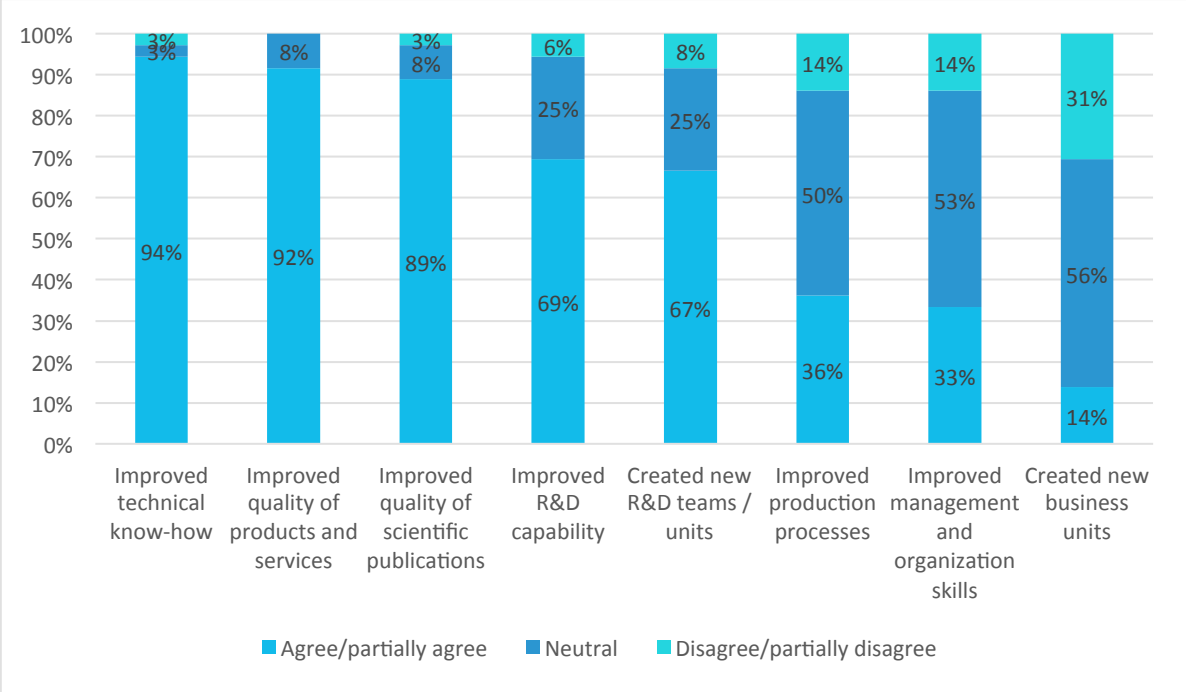


EO contribution to companies' economic performance

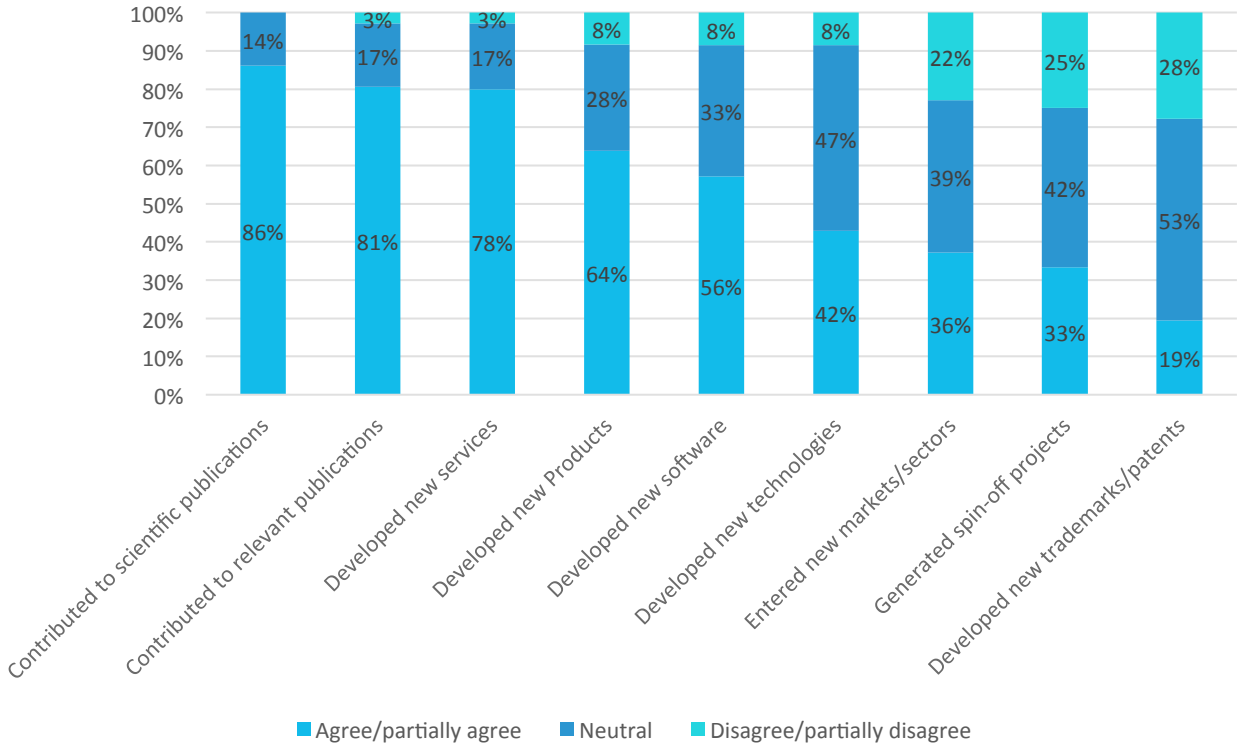


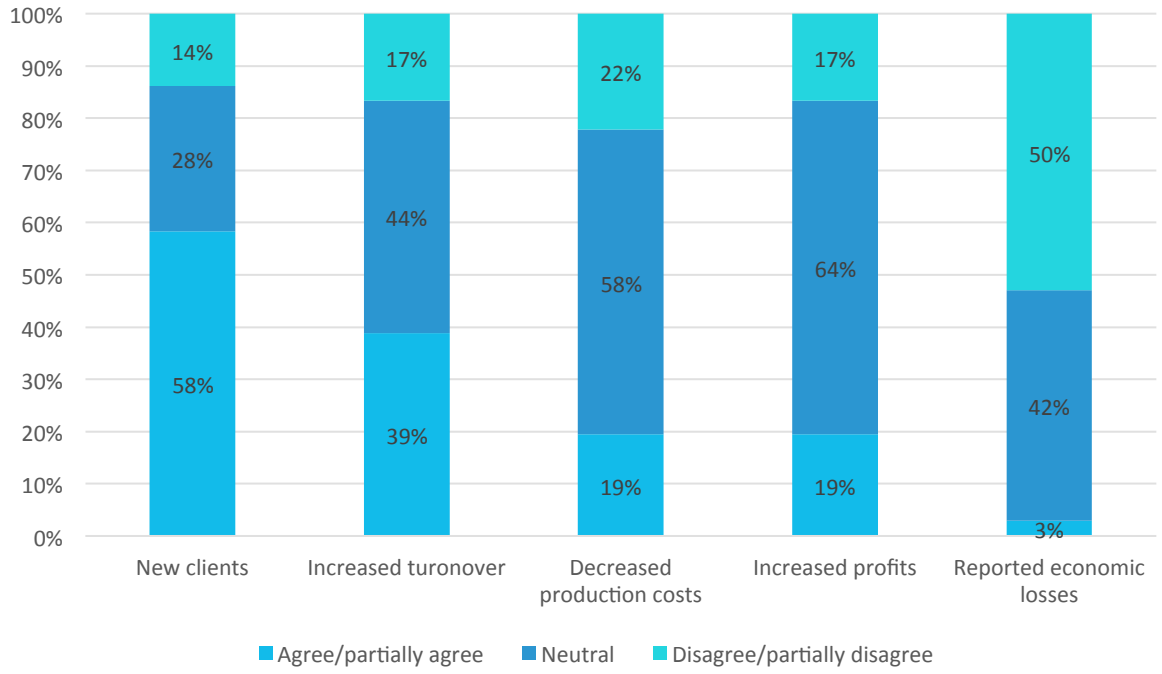
As regards **research centres**, according to 94% of researchers the availability of EO data has contributed to the improvement of their centre's technical *know-how*. The majority of the surveyed researchers (92%) say they have improved the quality of the offered products and services thanks to EO data, whereas 69% of them have increased their research & development capabilities. 67% of researchers have started new research & development teams/units, whereas 14% of them have contributed to create new business units. As regards production processes and management and organizational skills, in both cases, one third of the sample say they have made significant improvements thanks to the use of EO data. The improvement of scientific publication has been relevant (89%). 78% of researchers say they have developed new services, 64% of them say they have developed new products whereas 56% of researchers say they have created new software. 42% of centres have developed new technologies, whereas 86% of researchers have contributed to the production of scientific publications. 36% of the surveyed researchers have entered new markets or sectors and 33% of intermediate users have registered new *spin-off* projects. Furthermore, 19% of research centres have developed new brands and patents. The researchers from research centres say they have increased their number of customers (85%), their revenues (39%), they have reduced their production costs and increased their profits (19%). 50% of researchers say that, thanks to EO data, the number of temporary employees has increased; 36% of researchers say that, thanks to EO data, the number of permanent employees has increased whereas, according to 44% of them, the number of partnerships with self-employed workers has increased.

EO contribution to research centres' process innovation



EO contribution to research centres' output and product innovation





The results discussed so far only involve the impact on intermediate users, and overlook the added value that services and applications provided by such users can generate for end users. As regards the **socio-economic benefits for end users**, **companies** expect a significant increase of profits in the field of agriculture (57% of respondents), environmental ecosystems and pollution (49%), emergency and civil protection (48%), weather and climate applications (43%) and smart cities (41%). It must be highlighted how companies think that the sector of safety and defense is relevant (48%). About 26% of the surveyed companies think that agriculture, forestry and fishing might be the ATECO sector which may benefit the most from the adoption of EO data. 12% of the surveyed companies have mentioned public administration and the sector of defense, whereas 7% of them have mentioned scientific and professional activities. As regards social impact, instead, companies have been asked to indicate which sustainable development goals (SDGs), in particular, their EO services are helping to achieve. The first goal that has been mentioned is SDG 13 ("Take urgent action to combat climate change and its impacts") with 12% of answers, followed by SDG 9 ("Build resilient infrastructure, promote sustainable industrialization and foster innovation") with 11% of answers. SDG11 ("Make cities and human settlements inclusive, safe, resilient and sustainable") follows in third place (10%). As regards the contribution to SDGs 9 and 11, these are more peculiar for companies

which operate in the Italian market, since their European counterparts have given less credit to the contribution of their EO to these purposes (EARSC, 2020).

The surveyed **researchers** expect a significant increase in profits in the sectors of environmental ecosystems and pollution (65%), education, training and research (63%), weather and climate (50%), agriculture (48%) and smart cities (43%). It should be noted how the choices by intermediate users in the field of research are identical – even though with different percentages – to those mentioned by the surveyed companies. The surveyed researchers have identified in the Sustainable Development Goals (SDGs) "Strengthen the means of implementation and revitalize the global partnership for sustainable development" (17%) "Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels" (12%) and "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (10%) the main goals that can be reached with the help of EO data. According to the whole respondent sample, the EO data have an impact also on all the other SDGs, even though with lower percentages.

As regards the **main obstacles to the spread of EO products and services,** based on the results of the survey **companies** in the downstream sector don't seem to experience any specific difficulties in terms of access to data. Only 14% of companies say they experience (often or very often) issues in terms of cost of data. Another minor issue is related to the historical data coverage; in fact, only 10% of companies say that the offered time series aren't suitable to effectively develop their own services. At the same time, only 6% of companies say they experience issues in terms of access to data or geographical data coverage, whereas 5% of them experience issues which are related to technical characteristics of data and interaction with the supplier. As regards the relationship with the data provider, specifically, 38% of companies say they have, often or very often, a stable relationship. Similar percentages can be found when companies are asked whether they have received support from the data provider. At least in 35% of cases, a solution has been reached with the data provider in case of unexpected situations. Furthermore, most intermediate users have never stopped their relationship with the data provider due to technical difficulties.

A specific obstacle for companies regards the recruitment of qualified staff. 43% of companies experience (always or often) difficulties in terms of recruitment, whereas 19% of them say they don't experience such issues, or experience them only rarely. In line with

the European reality (EARSC, 2019), the surveyed companies are mainly looking for professionals dealing with programming and development (84%), analytical skills (81%), managerial and organizational skills (48%) and communication and marketing skills (37%).

Another type of obstacles to the development of the intermediate user sector regards the perception of products and services related to EO and, especially, the factors which limit the spread of EO services and applications of the surveyed companies among end users. Among these factors stand out the poor knowledge of opportunities deriving from EO (71%), the lack of staff with technical skills who is capable of understanding the information (63%), too much bureaucracy (56%), the aversion to the use of innovative tools (51%) and too high costs (48%).

As regards **researchers,** 20% of them experience issues in terms of access to data, whereas a further critical element, based on the answers provided in the *survey*, is the availability of a suitable geographical and historical coverage (20%). 14% of researchers experience issues which are related to the technical characteristics of data, whereas 10% of them experience issues when they interact with the data provider. 56% of researchers say they have, often or very often, a constant relationship with their data provider. The respondents say they have reached a solution with their data provider in case of unexpected situations (28%). Most intermediate users have never stopped their relationship with the data provider due to technical issues. As regards the perception of the main obstacles to the spread of the use of EO data among end users, we can observe how the lack of staff with technical skills who is capable of understanding the information (81%) is regarded as the first obstacle, followed by the poor knowledge of opportunities deriving from EO data (68%), the aversion to the use of innovative tools (51%), too much bureaucracy (46%) and too high costs (30%).

As regards the **aggregate economic impact**, the direct impact of the EO sector on economy is about 121,380,000 euros in added value per year for companies (ORBIS data) and about 75 million euros for research centres. For companies, this result comes from the product of the number of employees stated in the survey and the added value for employee obtained from ORBIS budget figures (average 2014-2020). For research centres, this result is obtained by multiplying the data on the number of employees stated in the survey by an estimate of the average value of salaries, starting from the salary of an associate professor.

As regards the direct cost-benefit ratio (which excludes the indirect and induced effects), the direct benefit is obtained by considering the gross operating profit on revenues for companies (15.4%, based on ORBIS budget figures, 2014-2020) and a similar gross margin for the other intermediate users (which is equal to 5%, based on a prudential estimate). Considering the number of employees stated in the survey, and average revenue for each

employee, the gross operating profit for companies is 40,683,620 euros. For research centres, an added value-turnover ratio of 80% has been prudentially estimated, which leads to a margin of 4,700,000 euros. In terms of costs, since upstream investments are paid back upstream, as we have previously observed, the social cost to be considered is the operating cost of the ASI's EO satellites and the Italian pro-rata cost of the Copernicus Sentinel/ESA satellites (the pro-rata cost of the Copernicus/ESA satellites is assumed to be equal to the average cost for ASI satellite although, from a qualitative perspective, conclusions wouldn't change even if the ESA cost was higher). The estimated cost is 21,706,667 euros. It follows that the estimated direct cost-benefit ratio is 2.1 = (40,683,720 + 4,700,000)/21,706,667. Therefore, every euro of public spending in the downstream EO sector, generates 2.1 euros of economic benefit for the Italian taxpayer, without considering the overall final impact (that is, keeping into account the impact generated on end users, for which further studies will be needed).[8]

3.3 Impact on scientific research

The available information has allowed to identify 1320 contracts from 1996 to 2018, including 672 contracts signed with 216 university units (university research centres, faculties, departments and universities) and the remaining 648 contracts signed with 124 public research centres. The total amount of partnership contracts between the ASI and universities in the time interval of interest is about 427 million euros, whereas the total amount of the contracts signed with public centres is about 187 million euros. The wide majority of centres with which the ASI works includes universities or public research centres, located in the Italian territory (1285 contracts, equal to 97.35%).

The partnership with the Italian Space Agency gives rise to a few effects, which can be divided in **intermediate (or direct) effects or final (or indirect) effects**. Within our

[8] The estimate of the cost-benefit ratio is obtained from a sample of 85 companies and 150 research centres and other organizations. As regards companies, the used value takes into account the fact that a few companies in our sample might be marginal users of EO data. As regards research centres, 100 of them can be found in the list of COSMO SKYMED or PRISMA data users. However, we should take into account the fact that in Italy there are 15,934 Copernicus users, and the survey with companies shows that 33% of respondents only use Copernicus or NASA data, whereas they never use COSMO SKYMED or PRISMA data. Taking into account the fact that, among Copernicus users, there may be several students and amateur users, and waiting to expand mapping of research centres, we can consider in an extremely conservative manner a further number of 50 research centres which use EO data as intermediate users. Based on even more prudential estimates of the number of companies and research centres (80 and 100, respectively), the cost-benefit ratio reaches a value of 1.9, whereas by assuming a number of 90 companies and 237 research centres we obtain a value of 2.3.

analysis, we have identified as indirect improvements all those effects – perceived by the *survey* respondents – which are immediate and related to the research team processes and activities.

Over 78% of respondents say they have improved their technical *know-how* thanks to their partnership with the ASI, whereas 77% of them say they have improved their research & development capabilities. Nearly 71% of the respondents say they have improved, thanks to this partnership, their project management and organizational skills, whereas 70% of them say that, by working with the ASI, they have improved the quality of the offered products and services. Only 7% of the respondents don't think that the partnership with the ASI has improved their organization's management skills.

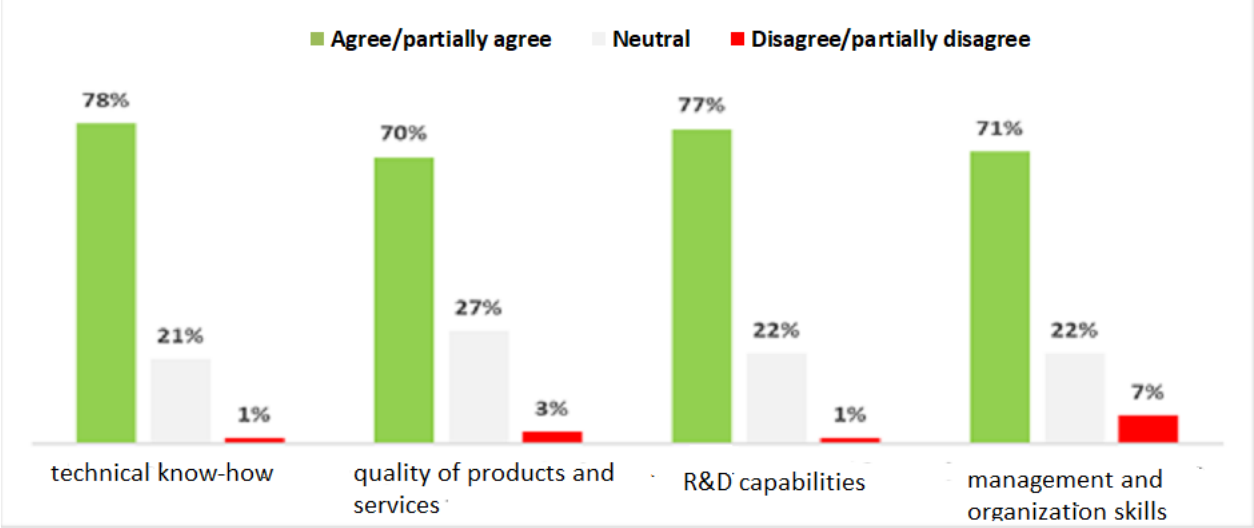
The presence of direct effects, such as the ability to develop new technologies, is mentioned by 75% of the sample, whereas the increase in the number of training projects or curricula which are directly related to the object of the partnership is mentioned by 82% of respondents; the development of new patents, copyrights or other intellectual property rights is substantiated by less than 25% of the respondents; finally, the increase in the number of master's or PhD theses which have been supervised along with the ASI, related to the object of the partnership, has been mentioned by 60% of the sample.

Almost 18% of the respondents say that, since the beginning of their partnership with the ASI, they have developed *spin-off* projects, whereas 75% of the respondents say that their organization has been able to start partnerships related to the object of the ASI contract. Furthermore, the partnership with the ASI has allowed to attract more funds for research on topics related to the object of the contract (71.2%) and guarantee a reputation improvement which has led to an increase in partnerships or research funds which are not directly related to the object of the ASI contract (72.6%). Finally, according to 89% of the respondents, the partnership with the ASI has been accompanied (or followed) by an increase in the number of scientific publications, whereas according to 57.5% of the respondents the relationship has led to an increase in the number of researchers working for the organization.

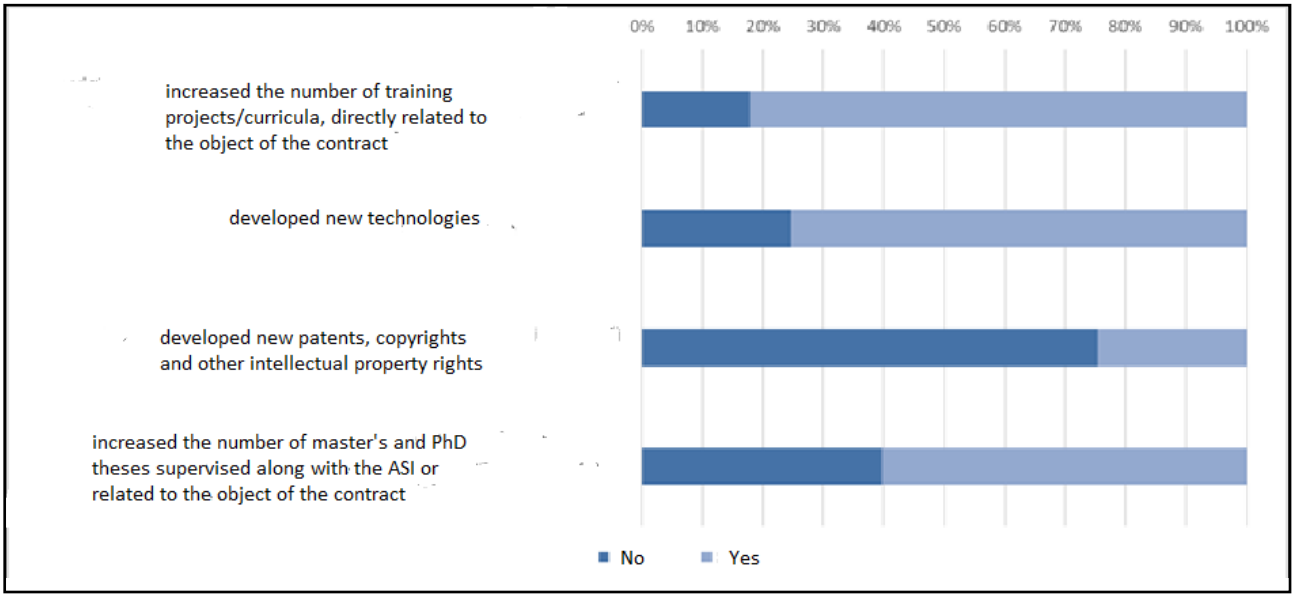
Another indirect or final impact of the partnership relationship with the ASI, which usually manifests itself a few years after the beginning – and sometimes a few years after the end – of the project, is the publication of journal articles, with a higher impact than the articles previously written by the members of the research group. In 27% of cases, the respondents say that the impact of the journals, where the results of the projects with the ASI have been published, has "moderately increased", whereas, in 29 % of cases, the

impact factor of the journals where the research results have been published has "significantly increased".

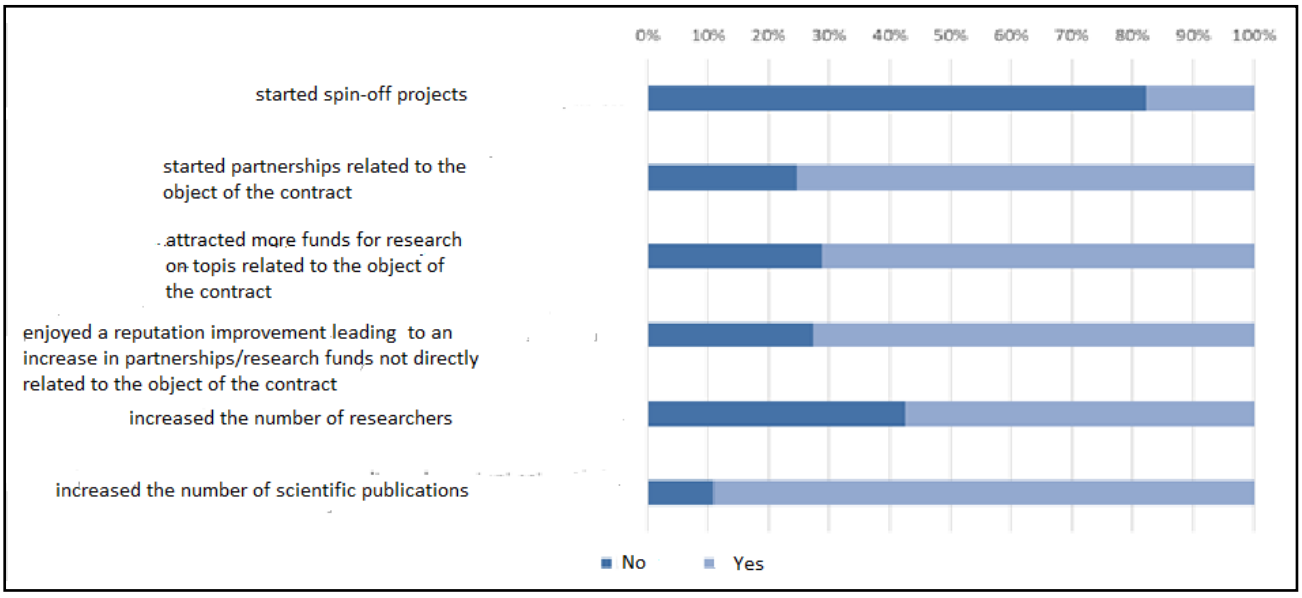
Thanks to the partnership with the ASI, since the beginning of the partnership, your organization has improved…



Direct effects. Since the start of the partnership with the ASI, your organization has…



Indirect effects. Since the beginning of the partnership with the ASI, your organization has…



The results of the online *survey* have shown how the research centres involved in partnerships with the ASI perceive such partnership as a trigger which can lead – although indirectly – to an increase in the quality of their scientific activity. This evidence, which comes from the answers to the direct survey, has been confirmed **by the analysis of the scientific publications which report the ASI as one of the financing bodies**. In the period 1989-2017, 3141 articles were published, written by a total of 13,690 authors. By comparing the number of citations obtained by such articles with those obtained by all articles written in the same period by the same authors (a total of 305,174 articles), the parameter estimations show a higher impact of the citations of scientific publications, ranging from 11-17% to 36% (in case of exclusive funding by the ASI).

A further scientometric analysis has analysed those **publications which use COSMO-SkyMed data**. In the 1996-2018 period, 1235 scientific contributions were published which are related to COSMO-SkyMed (works which are related with both the upstream and the

downstream sector). 2377 authors have been identified, with an estimated benefit based on the social value of the research time ranging from 32.4-37.4 million euros, including the value of citations.

4. Conclusions

Considering the analysed sectors, upstream companies and downstream intermediate users, as a whole, the socio-economic benefit – taxpayer cost ratio looks positive (that is, higher than 1) and is particularly high in the downstream EO sector, although with widely prudential estimates. As regards the upstream sector, the econometric analysis has shown a significant effect of *procurement* on economic performance and innovation. Also for the downstream sector (companies and research centres) the description of the results of the online survey shows a positive effect of the Earth observation data on economic performance and innovation. Finally, we have observed a significant impact of the ASI also on scientific productivity.

From a qualitative perspective, thanks to a few targeted interviews, the study has made clear how the impulse to learning mechanisms by the stakeholders, directly or indirectly provided by the ASI through its participation in the ESA, lies at the core of the observed impacts. The urge to solve scientific and technological frontier problems creates *"learning by doing"* effects, which result in research and development & innovation.

Bibliographical references

Ankrah, S., Omar, A. T. (2015). Universities–industry collaboration: A systematic review. Scandinavian Journal of Management, *31*(3), 387-408.

Aschoff B., Sofka W. (2009). Innovation on demand-can public procurement drive market success of innovations? Research Policy, 38(8): 1235-1247.

Autio, E. (2014). *Innovation from big science: Enhancing big science impact agenda*. London: Imperial College Business School.

Bozeman, B. (2000). Technology transfer and public policy: a review of research and theory. Research policy, 29(4-5), 627-655.

Castelnovo P., Florio M., Forte S., Rossi L., Sirtori M., (2018). The economic impact of technological procurement for large-scale research infrastructures: Evidence from the Large Hadron Collider at CERN. Research Policy 47(9), 1853–1867.

Clark, H., Pinkovskiy, M., Sala-i-Martin, X. (2017). *China's GDP growth may be understated* (No. w23323). National Bureau of Economic Research.

Cohen, W. M., Nelson, R. R., Walsh, J. P. (2002). Links and impacts: the influence of public research on industrial R&D. Management science, *48*(1), 1-23.

Costinot, A., Donaldson, D., Smith, C. (2016). Evolving comparative advantage and the impact of climate change in agricultural markets: Evidence from 1.7 million fields around the world. Journal of Political Economy, *124*(1), 205-248.

D'Este, P., Patel, P. (2007). University–industry linkages in the UK: What are the factors underlying the variety of interactions with industry? Research policy, *36*(9), 1295-1313.

Edquist, C., Zabala-Iturriagagoitia J. M. (2012). Public procurement for innovation as mission oriented innovation policy. Research Policy, 41(10): 1757-1769.

ESA (2012). Annual report. Available at

https://www.esa.int/About_Us/ESA_Publications/Historical_ESA_Annual_Reports/ESA_Annual_Report_2012 (Accessed: 11/30/2021).

Ghisetti, C., (2017), Demand-pull and environmental innovations: estimating the effects of

innovative public procurement, Technological Forecasting and Social Change, 125: 178-187.

Graziola, G. (2009), Perspectives and multiplier effects of the investments in high-technology sectors in advanced economies, with specific reference to the space sector in Europe. Report commissioned by the ASI to the University of Bergamo, Department of Economics.

Henderson, J. V., Storeygard, A., Weil, D. N. (2012). Measuring economic growth from outer space. American Economic Review, *102*(2), 994-1028.

Hodler, R., Raschky, P. A. (2014). Regional favoritism. The Quarterly Journal of Economics, *129*(2), 995-1033.

Inglada, J., Arias, M., Tardy, B., Hagolle, O., Valero, S., Morin, D., Koetz, B. (2015). Assessment of an operational system for crop type map production using high temporal and spatial resolution satellite optical imagery. Remote Sensing, *7*(9), 12356-12379.

Intesa Sanpaolo, Research department (2021). Space: new frontier for economy and research, November 2021.

Kalia, A. C., Frei, M., Lege, T. (2017). A Copernicus downstream-service for the nationwide monitoring of surface displacements in Germany. *Remote Sensing of Environment*, *202*, 234-249.

Kern, S., Spreen, G. (2015). Uncertainties in Antarctic sea-ice thickness retrieval from ICESat. Annals of Glaciology, *56*(69), 107-119.

Lee, Y. S. (2018). International isolation and regional inequality: Evidence from sanctions on North Korea. Journal of Urban Economics, *103*, 34-51.

Mansfield, E. (1991). Academic research and industrial innovation. Research policy, *20*(1), 1-12.

Martin, B.R. and Tang, P., (2007). The benefits from Publicly Funded Research, SPRU Electronic. Working Paper Series, Paper no. 161. University of Sussex, Brighton.

Marx, B., Stoker, T. M., Suri, T. (2019). There is no free house: Ethnic patronage in a Kenyan slum. American Economic Journal: Applied Economics, *11*(4), 36-70.

Mazzucato, M. (2016). From market fixing to market-creating: a new framework for innovation policy. Industry and Innovation, *23*(2), 140-156.

OECD (2017). Public Procurement for Innovation. Good Practices and Strategies, OECD Public Governance Reviews. OECD, Paris.

Onoda, M., Young, O. R. (2017). *Satellite earth observations and their impact on society and policy*. Springer Nature.

Perkmann, M., Tartari, V., McKelvey, M., Autio, E., Broström, A., D'este, P., Sobrero, M. (2013). Academic engagement and commercialisation: A review of the literature on university–industry relations. Research policy, *42*(2), 423-442.

Salter A.J., Martin B. (2001). The economic benefits of publicly funded basic research: a critical review. Research Policy, 30(3): 509-532.

Schmidt, A., Leadbetter, S., Theys, N., Carboni, E., Witham, C. S., Stevenson, J. A., Shepherd, J. (2015). Satellite detection, long-range transport, and air quality impacts of volcanic sulfur dioxide from the 2014–2015 flood lava eruption at Bárðarbunga (Iceland). Journal of Geophysical Research: Atmospheres, 120(18), 9739-9757.

Seely, B. E. (2008). Editorial introduction: NASA and technology transfer in historical perspective. Comparative Technology Transfer and Society, 6(1), 1-16.

Storeygard, A. (2016). Farther on down the road: transport costs, trade and urban growth in sub-Saharan Africa. The Review of Economic Studies, *83*(3), 1263-1295.

Venturini, K., Verbano, C. (2014). A systematic review of the Space technology transfer literature: Research synthesis and emerging gaps. Space Policy, *30*(2), 98-114.

Von Schuckmann, K., Le Traon, P. Y., Alvarez-Fanjul, E., Axell, L., Balmaseda, M., Breivik, L. A., Verbrugge, N. (2016). The Copernicus marine environment monitoring service ocean state report. Journal of Operational Oceanography, *9*(sup2), s235-s320.

Vuola, O., Hameri, A. P. (2006). Mutually benefiting joint innovation process between industry and big-science. Technovation, *26*(1), 3-12.